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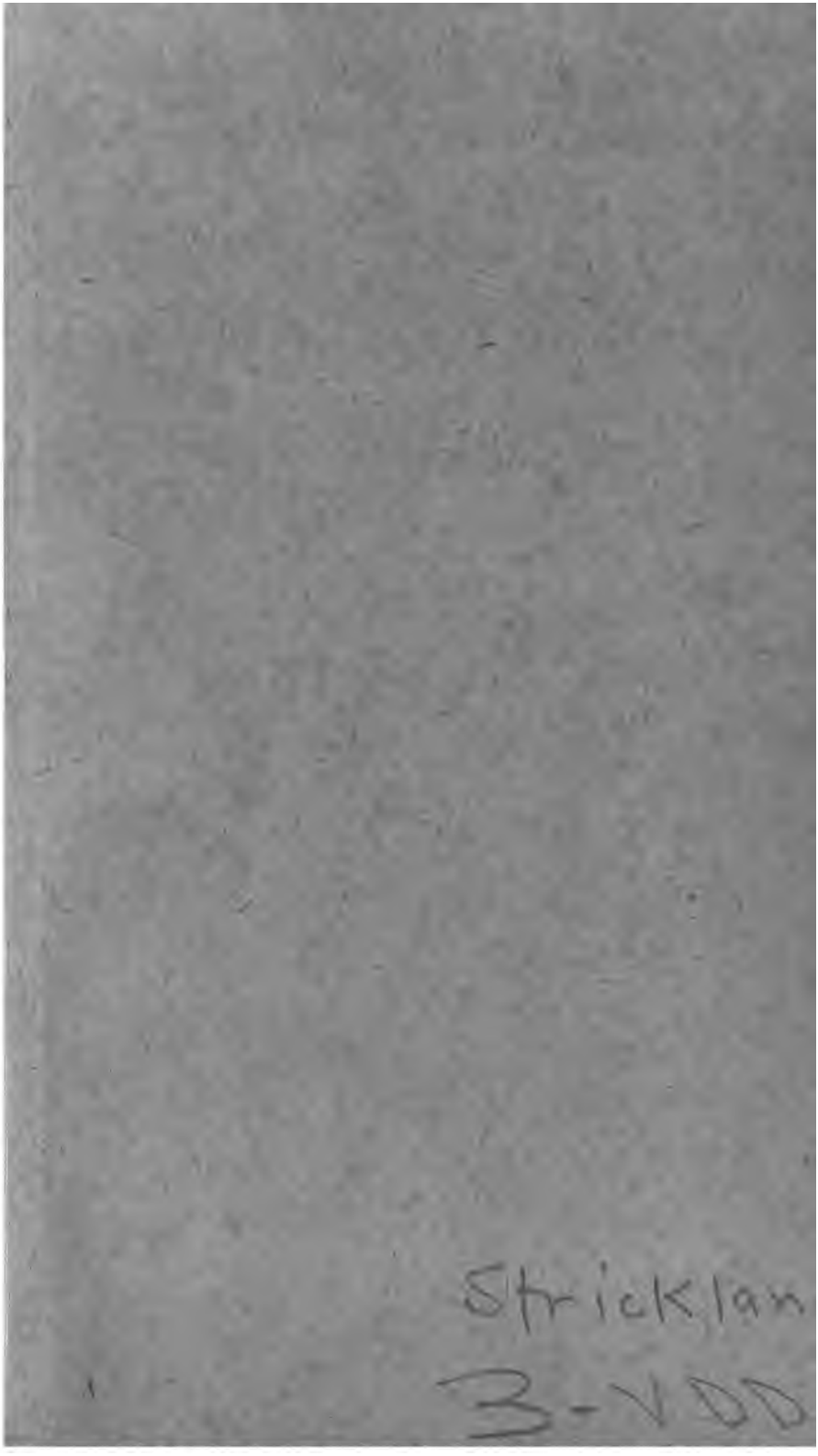
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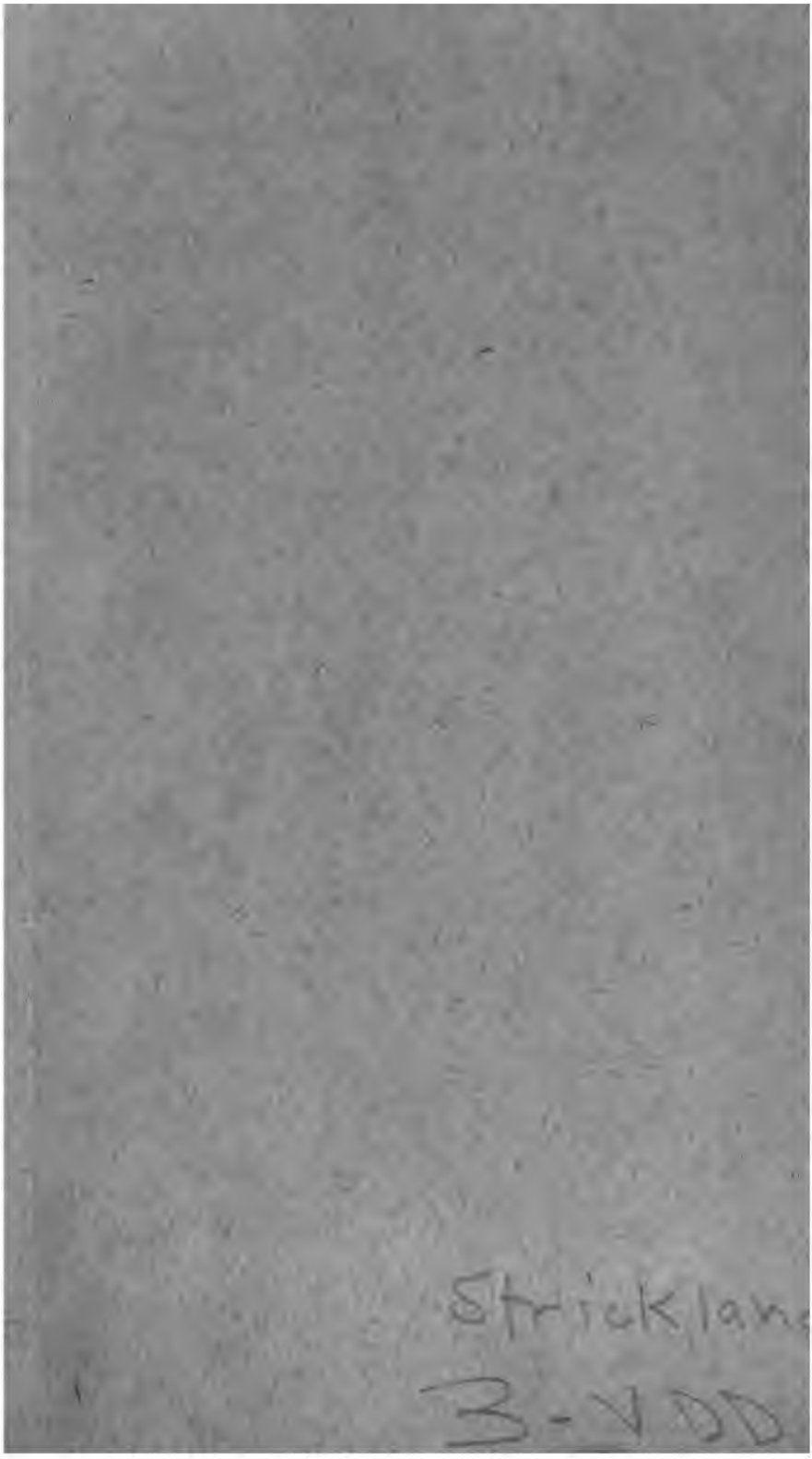
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REPORTS, SPECIFICATIONS, AND ESTIMATES

OF

PUBLIC WORKS

IN THE

UNITED STATES OF AMERICA:

COMPRISING

THE PHILADELPHIA GAS WORKS.
RESERVOIR DAM ACROSS THE SWATARA.
TWIN LOCKS ON THE SCHUYLKILL CANAL.
DELAWARE BREAKWATER.
PHILADELPHIA WATER WORKS.
DAM AND LOCK ON THE SANDY AND BEAVER CANAL.
DAM ON THE JAMES RIVER AND KANAWHA CANAL, VIRGINIA.
LOCKS OF EIGHT FEET LIFT, ON THE SAME.
AQUEDUCTS ACROSS RIVANNA RIVER AND BYRD CREEK, ON THE SAME.
SUPERSTRUCTURE, ETC., OF FARM BRIDGES, ON THE SAME.
LOCK GATES AND MITRE SILLS.

EDITED BY

WILLIAM STRICKLAND, Architect and Civil Engineer.
EDWARD H. GILL, Civil Engineer.
HENRY R. CAMPBELL, Civil Engineer.

EXPLANATORY OF THE ATLAS FOLIO OF

DETAILED ENGRAVINGS

ELUCIDATING THE ENGINEERING WORKS HEREIN DESCRIBED.

LONDON: JOHN WEALE.

M.DCCC.XLI.

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PUBLIC WORKS

OF

THE UNITED STATES OF NORTH AMERICA.

THE PHILADELPHIA GAS WORKS.

The Philadelphia Gas Works represented in Plates I. to XIII. were constructed in the year 1835, under the direction and superintendence of Samuel V. Merrick, Esq., Engineer.

The plan was matured after a minute examination (by direction of the City Councils of Philadelphia) of the principal works in America and Great Britain, and intended to embrace the latest improvements in the art.

The Works are located on the Schuylkill River, upon three distinct squares: 1. The wharf lot, which has a front of 306 feet on the river by 190 feet in depth.—2. The works lot, 306 feet by 240.—3. The gasometer lot, 306 feet by 273;—the last two being surrounded by streets.

The plan originally designed was deemed sufficient for the immediate wants of the city, but was so arranged as to admit of a systematic enlargement to meet the increasing demand with perfect symmetry in all its parts.

The gasometer lot, when filled, will contain sixteen gasometers, each 50 feet in diameter and 18 feet in depth, and afford capacity for 560,000 cubic feet of gas. At present four are in action, and four more in the course of construction.

The Works are laid out in eight distinct sections of ten "benches," or thirty retorts each, making an aggregate of two hundred and forty retorts. Each bench yields upon an average 10,000 cubic feet of gas daily, or, when in full action, an aggregate of 800,000 feet.

To each section is a distinct washer, purifier, condenser, and station meter. The two retort-houses are each 200 feet long and 50 feet wide, located in the centre of the square, having between them a passage of 40 feet, which is excavated as a cellar and floored over water-tight. This passage and the arched cellars under the retort-houses serve as coal stores.

Each retort-house contains one stack and four sections of retort benches, built back to back down the centre of the building on each side of the chimney. The apparatus for cleansing the gas is located to the north and south of each retort-house respectively. Two sections of retort benches are now completed and in action, and a third is now in the course of erection.

The retorts are the broad or York D's, 20 inches by $7\frac{1}{2}$ feet in the clear, set upon an original plan.

The gas is washed in two waters through washers of simple construction, with valves so arranged as to use either as the first, the most pure water being used as the second. The condensers are of ordinary construction, modified so as to enlarge the receptacle for the residuum at the base of the columns. The puri-

fiers are constructed for dry lime, with a hydraulic seal for shifting, by which the use of valves in the purifying house is avoided.

After passing the meters, the gas from all the sections mingles in the gasometers or gas-holders.

A description of the process of manufacture is deemed unnecessary, as it is familiar to most readers.[1]

In compliance with the request of the stockholders and others interested in the progress and success of the Philadelphia Gas Works, the following Annual Reports of the Trustees to the City Councils, and other documents relating to the establishment, were published in 1838, together with the instructive and interesting Report of Mr. Merrick, to whom the examination of the principal gas works of Europe had been delegated: these embrace "almost a complete history of the Works, from the first proposal of the undertaking in the year 1832," and are introduced by the following prefatory remarks:

"In the search for materials, the Trustees felt a natural anxiety to ascertain the name of the individual with whom the idea of lighting this city with gas originated. A gentleman who was at one time an active and highly valuable member of Councils, (the late John B. Wallace, Esq.,) had, a few years since, informed one of the Trustees that the plan was

[1] The Editors are indebted to S. V. Merrick, Esq., Engineer of the Works, for the above description, and to J. C. Cresson, Esq., Superintendent, for his politeness in exhibiting the Works and various details, &c., &c.

first suggested by the late Dr. Bollmann, whose taste for and great acquirements in science are well known. This was rendered the more probable, as Dr. Cooper, in the preface to his Essay on Gas-lights, (which appeared in 1816,) alludes to that gentleman as having furnished him information in relation to the manufactories of gas in Europe.

"A diligent search was made of the Minutes of Councils, in relation to this subject, from the year 1795 down to the present time; and the first notice of gas was found to be in the following words:—

"1815, Dec. 28.—In Common Council.

"A letter from James M'Murtrie, on the subject of introducing gas-lights in the city, was read, and laid on the table."

"The letter stated that he was on terms of great intimacy with the late Dr. Bollmann; they had shortly before returned together from Europe, where they had carefully examined the recently established gas works of England. We understand that they were to be united in the management of the establishment; and we believe that the intention then was to manufacture the gas from wood. It was Dr. Bollmann's desire to connect this manufactory with that of pyroligneous acid, which was to be used in the preparation of white lead, upon the plan of the works at Clichy, in France; of the success of which it is well known that he felt very sanguine.

"Whether the manufacture of gas could have been successfully established about that time or not, is a question of some interest, but upon which we have not sufficient data to decide. Experiments made then, or soon after, in Baltimore, New York, and other

cities, were very far from successful. The filth, the stench, the nuisances of various kinds, and the pecuniary losses attending those establishments, not only prevented our city from following the example, but they created on the part of a large, intelligent, and respectable portion of our community, exercising necessarily great influence over our Councils, so deep-rooted a prejudice against gas-lights, as to prevent, for many years, the success of all applications to Councils to countenance them; and when finally the re-action in the public mind, chiefly in the younger portions of the community, forced the subject upon their attention, it produced one of the most exciting questions ever brought before them.

"Those, however, who most violently opposed it, and who have had the candour since to acknowledge their error, will recollect that many of them were the active agents in introducing into our city the greatest of all comforts—an exhaustless supply of wholesome water; and that while they were great benefactors to the community, they had to overcome the opposition of many a *laudator temporis acti*.

"It appears to have been in the autumn of 1830, that the discussion of the subject was again revived. A petition was presented by a number of gentlemen to Councils, asking them to sanction an intended application to the Legislature for a charter to incorporate a company to manufacture gas for lighting the city and liberties of Philadelphia. The application was refused, but a committee of inquiry was appointed. Mr. Lippincott, who was a member of that committee, appears to have been from that time until his retirement from Councils in the autumn of 1835, an active, intelligent, and zealous friend to the measure.

" The first step, however, connected with the present Works may be considered to have been taken after the election in the autumn of 1832, when the unfinished item in relation to the lighting of the city with gas was referred to a committee, consisting of Messrs. Lippincott, Wetherill, and Eyre, of Select Councils; and Messrs. Merrick, Huston, and Gilder, of Common Councils.

" During the progress of these inquiries, several applications had been made by individuals or companies for the privilege of establishing gas works at private expense, offering to Councils terms more or less advantageous to the public; but these were all declined; fortunately, as it has turned out, since it has resulted in the establishment of Works which are believed to combine peculiar advantages. The present Works being the private property of individuals associated for this purpose, there is a disposition to avoid those extravagant expenditures or unjustifiable extensions which are frequently the cause of failure and bankruptcy in Works carried on at public expense; while the general control of the Works and the selection of the agents remaining entirely in the hands of the city authorities, the public good is not made subservient to private interests; and the Trustees may perhaps be permitted to state here, that in the deliberations of the Board to which they had the honour of being appointed by Councils, they have felt themselves invested with a high, honourable, and responsible *trust;* they have considered themselves really as acting the part of *Trustees*, whose duty it was to advance the interests of their stockholders to the fullest extent compatible with the rights and interests of the public at large."

REPORTS, &c.

First Annual Report made to the Select and Common Councils of the City of Philadelphia.

In obedience to the fourth section of the ordinance for the construction and management of the Philadelphia Gas Works, the Trustees present the following statement of their proceedings and of their receipts and disbursements since the time of their election.

The City Treasurer, in conformity to the ordinance, opened a book for subscriptions to the capital stock on the first Monday in April, 1835, and the whole amount was promptly subscribed for.

This enabled the Trustees to proceed at once in making plans and contracts for the furtherance of the undertaking. Accordingly, after obtaining the services of an accomplished engineer, they lost no time in engaging workmen, making contracts, and collecting materials of every description for the erection of the buildings; so that scarcely a month had elapsed from the enactment of the ordinance before the buildings were commenced, orders issued, and contracts made for nearly every thing pertaining to the Works.

The buildings are erected on the ground appropriated in the ordinance for the location and use of the Gas Works, fronting on the river Schuylkill, north of High-street.

The plan, as projected by the engineer and adopted by the Trustees, is not only tasteful and convenient, but calculated for extension of the different parts from time to time, as the wants of the city may require, without affecting the symmetry of the whole. It contemplates a series of Works, calculated to occupy all the ground appropriated, excepting, perhaps, a part of the water front, and capable of manufacturing gas sufficient for twenty-four thousand argand burners. When

fully extended, the Works will consist of six sections, each one being complete in itself for the manufacture and retention of gas.

Part of the general plan consists of a section of one retort-house with its lime and purifying house, two gasometers with tanks of masonry, an office on the west side of Ashton-street, and a range of shops between the office and Filbert-street, behind the enclosing walls of the Ashton-street front. Of these, the retort-house, lime and purifying house, office and shops, are finished, and require only a few incidental arrangements to be in complete working order.

Enough retorts are set to supply any probable demand for gas for some time to come, and others are in readiness to be put up whenever they may be required. The only matters of importance that remain to retard the operation of the Works are the fixtures of consumers and the gasometers. The former are made by persons employed by the consumers themselves, and are no otherwise controlled by the Trustees or their agents than to insure their fitness before gas is let into them. The gasometers are large iron vessels, each having a capacity of 34,000 cubic feet of gas, and require to be perfectly air-tight. They were contracted for very soon after the passing of the ordinance.

In their contract for cast-iron pipes for the distribution of the gas through the city, it was the good fortune of the Trustees not only to obtain them of good quality and at fair prices, but with a promptitude and regularity that greatly facilitated their operations. So that, notwithstanding the advanced state of the season when the work was commenced, the interruption from frequent heavy rains, and an extension of the pipes not contemplated, the agent intrusted with this department succeeded in laying the whole in good season.

The entire range of pipes now laid, exclusive of service pipes for consumers, and about 1,500 feet of branches, extends 38,652 feet, or about 7$\frac{1}{3}$ miles. Nearly all the cast-iron posts for the public lamps required by the city authorities are set; the service pipes attached to the mains

ready for the burners, and the lanterns are provided or under contract.

Many of the service pipes for the supply of consumers have likewise been laid, and a competent supply of gasometers are on hand; so that but little remains to be done in order to put the whole in complete operation.

When the shortness of the time is considered, during which so much has been accomplished under all the disadvantages incident to an undertaking new to the Trustees, and to most of the workmen employed, and the handsome and substantial manner in which the greater part of it is done, the Board think they may well congratulate Councils and the stockholders on the state of the Works. Great praise is due to the engineer for the intelligence and untiring industry with which he has pushed every part towards completion; and the credit of much faithfulness is likewise due to all the contractors, with a single exception.

The receipts during the past year have been only of the capital stock. This was called for in four successive instalments, at short intervals, as it was deemed desirable to secure at once such a disposable capital as to be able to meet with promptitude all the engagements of the Trustees, and to secure by cash payments the greatest economy and regularity in the execution of the contracts. The stock was raised by instalments, as follows:

First instalment, on subscribing, on the 6th of April, 1835	10 per cent.
Second instalment, June 1st, 1835 . .	30 ,,
Third instalment, July 15th, 1835 . .	30 ,,
Fourth instalment, September 1st, 1835 .	30 ,,
	100 per cent.

Notwithstanding the pressure in the money-market which has been felt for many months past, the stockholders exhibited an unusual degree of readiness in responding to the call of the Trustees; indeed, of the entire amount there remains at this time but $2,290 unpaid.

The disbursements have been as follows:

Expenditures[2] for the Works on the Schuylkill .	$44,137	28
,, Distribution (pipes laid in the streets)	42,661	41
,, Service pipes (branches from the main pipes) . . .	3,567	85
,, Public lamps for the streets, supplied by the Trustees, . .	1,504	01
,, Stock of bituminous coal laid in	1,488	50
	$93,359	05

In addition to the above, the engineer estimates that there will be required to complete the Works, and place them in a condition to become productive:

For gasometers, &c., &c., at the Works on the Schuylkill	$10,000	00
For service pipes to meet outstanding orders . .	2,150	00
For public lamps to complete the order of the Committee on Police	1,495	99
For an additional supply of coal	750	00
Making altogether	$14,395	99

Which exceeds the whole capital by the sum of 7,755 dollars 4 cents; besides which the accruing rents, salaries, and other incidental expenses not included in the estimate of the engineer, the Trustees think will amount to about 4,244 dollars 96 cents; making in round numbers 12,000 dollars, which it is probable will be required over and above the original capital, to meet outstanding orders and complete the Works on the scale now contemplated.

In explanation of this apparent excess beyond the original estimate, it is proper to state that *that* did not include certain expenses which at first it was not thought expedient to undertake; but which more reflection has satisfied the Trustees should be regularly assumed by the Board, and an allowance for them obtained in the price of the gas sold. Nor did it include the heavy expenditure incurred in sup-

[2] An approximation to the value in pounds sterling will be obtained by dividing the number of dollars by 5.

plying the fixtures and lamps for the streets, which the ordinance requires of the Trustees to provide without expense to the city. And the line of pipes, as originally proposed to be laid, has been greatly extended; in some instances at the request of the city authorities, where new paving of the streets was about to be undertaken by them; and in other cases at the request of persons who pledged themselves to become consumers of gas as soon as it could be furnished. Another considerable item included in the above account is the bituminous coal laid in for making gas. The items may severally be estimated as follows:

Service pipes and meters . . .	$5,715 85
Extension of pipes in certain streets beyond original amount	6,333 00
150 public lamps and fixtures, at 20 dollars each	3,000 00
Stock of coal	2,238 50
Expenses not estimated for	$17,287 35

Thus it will be perceived that the expenditures upon the objects originally proposed correspond very nearly with the estimates; and that the actual cost of erecting the Works is several thousand dollars less than the capital appropriated.

This result is the more satisfactory from the unlooked-for difficulties that were experienced in excavating the tanks, owing to the rocky and springy nature of the soil, which caused considerable additional expense; and the entire change in the system of labour which occurred very soon after commencing operations. To Councils and the stockholders it is especially interesting, as it tests very fully the accuracy of the calculations upon which the enterprise was commenced.

The experimental apparatus erected at the Works for the purpose of testing the quality of different samples of coal has been in operation for several weeks, and gas enough manufactured for the use of the office and buildings on the Schuylkill; and the engineer is of opinion that a full supply for consumers can be furnished in a very few days.

The applications already upon the books of the Trustees

will require an amount sufficient for twelve hundred argand burners, or about one-fourth of what can be manufactured by the present Works; and the Trustees believe that, before many months elapse, the demand will at least equal the whole capacity of the Works.

By order of the Trustees,

R. M. HUSTON, *President.*

Philadelphia, Jan. 26, 1836.

Second Annual Report made to the Select and Common Councils of the City of Philadelphia.

The Trustees of the Philadelphia Gas Works, in compliance with the provisions of the ordinances under which they act, submit the following report of their proceedings, and an account of their receipts and expenditures for the past year. With the capital of one hundred and twenty-five thousand dollars which was placed at their disposal for the construction of the Gas Works, the necessary buildings and apparatus for the manufacture of gas, with gas-holders for its storage, and an office and work-shops, have been erected on the lot belonging to the city between High and Filbert-streets, on the Schuylkill; nearly eight miles of iron mains have been carried through central parts of the city, and 268 buildings and 165 public lamps are now supplied with gas by branches connected with the street mains, and attached to meters placed within the walls of the buildings intended to be lighted.

The expenditures for the accomplishment of these objects have entirely exhausted the capital paid in; one hundred and twenty-five quarter shares of the additional stock remaining undisposed of, and the engagements of the Trustees for a supply of coal for the operation of the Works and for the completion of the apparatus, have compelled them to fix a time when they must cease taking customers, from their inability to furnish service pipes and meters, which it was deemed proper to supply out of the capital. On the 8th of February, 1836, the Works were so far completed as to

commence the manufacture of gas, and on the 10th of the same month the pipes of conduit were filled, and the public lamps in Second-street lighted. Owing to the tardiness with which those engaged in putting up the fittings for private burning proceeded with their work, only two premises were at that time prepared for the introduction of gas, and the whole demand on the establishment amounted to nineteen private and forty-six public burners. From the 8th of February to the 1st of September, the operations of the Trustees were necessarily unprofitable; owing to the irregularity of the demand during the summer months, the great proportion of the public burners which are not constantly lighted, the increased wear and tear of the apparatus by throwing portions out of work, and to the fixed expenses being nearly the same whether a large or small quantity of gas is made. The receipts for gas from February 10th to April 1st were $829 48; from April 1st to June 1st, $1,724; from June 1st to September 1st, $3,112 42; and for the quarter ending December 1st, $8,061 23.—From the 1st of September, 1836, the demand has been sufficient to give profitable employment to the Works, and the present daily consumption of gas is about 42,000 cubic feet, supplied to 2,800 private and 165 public burners. Fifteen retorts for the carbonization of the coal are now in use, and the Works have the capacity to supply about 75,000 cubic feet per day, which, with a small addition to the present capital, may readily be distributed and sold in those parts of the city where the pipes are already put down. The Trustees hope that by the acceptance of the ordinance recently passed by Councils, the stockholders will give them the means of effecting this, and extending the benefits of the Gas Works to other portions of the city, at the same time that they will insure to themselves a fair remuneration for the amount so liberally placed at the command of the Corporation for the interesting experiment which has now been so successfully made. The Works are built in the most substantial manner, and for the perfection and economy of their operation are certainly unrivalled in this country: the rapidity

with which they were constructed, and the complete adaptation of every part of the apparatus to its intended purpose, reflect the highest credit on the engineer, Samuel V. Merrick, Esq., whose faithfulness and ability in discharging the arduous and novel duties of the undertaking it gives us much pleasure thus publicly to notice. The gas is obtained exclusively from bituminous coal, and the coke produced by its carbonization is used at present as the principal fuel: considerable quantities of this residuum are sold for manufacturing and domestic purposes, and when the sale of it is more extended, anthracite coal will be introduced as the fuel for making gas.

The Trustees respectfully refer to the accounts hereto annexed for the details of their receipts and expenditures, and would suggest that they should be placed in charge of a Committee of Councils for the purpose of being audited.

In conclusion, the Trustees congratulate the Councils and their fellow-citizens on the complete success of the enterprise placed in their charge; for, independently of the increased cleanliness and comfort which have been obtained by the introduction of gas-lighting into our stores and dwellings, and the security afforded against accidents in the public streets in which the same means are employed for illumination, its value as an auxiliary to the police for the prevention of crime makes it very desirable that the whole city should participate in its advantages.

By order of the Trustees,

R. M. HUSTON, *President.*

Attested.—WM. FENNELL, *Registrar.*

Philadelphia, Jan. 19*th*, 1837.

Amount of Cash received by the Trustees of the Philadelphia Gas Works from March 21*st*, 1835, *to January* 1*st*, 1837.

For capital stock paid in . . .	$121,875 00
Consumption of gas . . .	13,727 13
Sales of coke, coal, tar, &c. . .	2,507 58
„ Service pipes, stop-cocks, &c.	1,279 11
	$139,388 82

Amount of Cash paid by the Trustees, &c.

For construction of Works . . .		$64,659 82
Distribution pipes		44,862 00
Service pipes, meters, &c. . .		12,064 94
Public lamps		2,591 40
Expenses of coal, freights, rents, salaries, wages to workmen, and incidental expenses		14,244 09
Balance—Cash on hand .	$851 92	
City Treasurer . .	114 65	
		966 57
		$139,388 82

January 1*st*, 1837.

Third Annual Report made to the Select and Common Councils of the City of Philadelphia.

The Trustees of the Philadelphia Gas Works, in compliance with the provisions of the fourth section of an ordinance for the construction and management of the Philadelphia Gas Works, enacted on the 21st day of March, 1835,

Respectfully submit

An accurate account of their receipts and disbursements, together with a statement of their proceedings during the past year. These will be comprised under the following heads:

1st. Of the manufacture of gas during the year 1837.

2d. Of the extensions and improvements undertaken during that year.

3d. Of contemplated improvements and extensions.

4th. Of the finances of the Company.

5th. Miscellaneous observations.

FIRST.—*Of the Manufacture of Gas during the year* 1837.

The Trustees have pleasure in reporting that the manufacture of gas has been uninterrupted during the whole year;

and that no accident has occurred, and no cause of complaint has been given, either as to the quality or supply of gas.

The following table exhibits a comparative statement of the quantity made during the years 1836 and 1837, and will show the rapid increase in the consumption, which almost entirely counteracted the reduction naturally expected during the summer months:

Gas was first made at the Works on the 8th of February, 1836; since which there was made,

	In 1836.	In 1837.
January,	———	1,156,400 cubic feet.
February,	205,200	1,006,200
March,	359,000	1,306,100
April,	362,300	1,104,400
May,	453,200	960,400
June,	361,600	866,400
July,	353,200	903,100
August,	442,300	1,078,100
September,	658,700	1,517,800
October,	921,200	2,119,700
November,	1,111,000	2,418,100
December,	1,253,600	2,642,200
Total	6,481,300	17,078,700[3]

The capacity of the Works now in operation is equal to the manufacture of 110,000 cubic feet in twenty-four hours.

The daily consumption at this time varies from 90,000 to 100,000 cubic feet.

The greatest consumption in any one day, up to the present time, has been 105,000 cubic feet.

The number of consumers at this time is 670.

The total number of burners now supplied is 6,814.

[3] The total amount of gas made in the year 1838 was 27,357,000 cubic feet, of which 25,634,534 cubic feet were sold; exhibiting a loss of 1,722,466 cubic feet. 109,500 bushels of coal were used in the manufacture of the above, and 158,000 bushels of coke made.

The public lamps supplied with gas amount to 301.

There are at this time four gasometers, all in good order for working, whose contents equal 140,000 cubic feet.

SECOND.—*Of the Extensions and Improvements undertaken during the year* 1837.

The works were originally commenced on a plan which admitted of a regular and symmetrical extension, as necessity would justify.

In the year 1835, the first section of the Works was commenced, and consisted of a retort-house, capable of receiving thirty retorts, of the requisite purifiers, condensers, coolers; of two gasometers for the retention of gas; of an office and workshops;—and were stated in the last annual report, as having a capacity to supply about 75,000 cubic feet per day. By adding to the number of retorts, and by judicious improvements resulting from increased experience, that section of the works has been brought to be equal to a supply of 110,000 cubic feet per day.

The second section of the works was commenced immediately after the acceptance by the stockholders of the ordinance for the extension of the Philadelphia Gas Works, passed on the 22d of December, 1836, and accepted by them on the 25th of January, 1837.

The extension has consisted in the enlargement of the retort-house, sufficiently to contain sixty additional retorts; of these, thirty have been constructed, and are ready for use. These, with the thirty already in operation, will suffice for the manufacture of 220,000 cubic feet in twenty-four hours. The rest of the retorts may be put in at any time hereafter, when required.

By a slight alteration in the disposition of the benches of retorts, erected in 1835, more space may be obtained; so that the house will be capable of receiving 120 retorts, which are sufficient to manufacture upwards of 400,000 cubic feet of gas every twenty-four hours.

The building originally used as a lime-house has been fitted up for the purifiers of the second section, and the necessary apparatus for washing, cooling, and condensing the gas, has been doubled.

Two new gasometers of equal size with those previously constructed have been completed.

Extensive coal stores, capable of receiving 100,000 bushels of coal, have been constructed, and will contain a stock equivalent to a six months' consumption of coal for the probable manufacture of gas during the next winter. A substantial brick wall has been constructed, so as to protect the buildings.

The cost of the new works was estimated by the superintendent as follows:

	AMOUNT PAID.	AMOUNT DUE.	TOTAL.
Stone	$2,423 15	$1,200 00	$3,623 15
Brick	3,310 15	698 98	4,009 13
Lumber	2,233 50	———	2,233 50
Castings, &c.	13,678 06	3,700 00	17,378 06
Roof Materials	2,250 92	———	2,250 92
Masonry	9,000 00	1,212 89	10,212 89
Excavating Tanks	1,796 93	———	1,796 93
Gasometers	6,000 00	4,000 00	10,000 00
Wages of Hands	8,941 19	1,500 00	10,441 19
Sundries	2,827 68	1,850 00	4,677 68
Fire Bricks	———	1,442 65	1,442 65
Total amount of present extension	$52,461 58	$15,604 52	$68,066 10

There was also paid last spring in order to complete the old works, the sum of . . . $2,138 43

Making the total amount expended in completing and extending the works $70,204 53

The distribution or system of main pipes in the streets has received great extensions during the past year.

The number and size of the pipes are as follow:

10 inch pipe . .	18 feet	
6 do. do. . .	6,984 ,,	
4 do. do. . .	4,302 ,,	
3 do. do. . .	13,068 ,,	
2 do. do. . .	3,468 ,,	
	27,840 feet, or	5¼ miles.
To which add pipes laid in 1835 and 1836 . .	41,603 feet, or	7¾ miles.
	69,443 feet, or	13 miles.[3]

The number of public street lamps erected at the expense of the Company in 1835 and 1836 was . 157
To which were added in 1837 . . 143
——300

for which (in accordance with the provisions of the fifth section of the ordinance of March 21st, 1835,) the fixtures and meters, being approved by the appropriate committee of Councils, were provided by the Trustees without expense to the city corporation, and have been regularly supplied at one half the price paid by private consumers.

The increased number of consumers has necessarily called for a large expenditure in meters and services. Notwith-

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[3] In the year 1838, the following pipes were laid:

2 inch pipe . .	150 feet
3 do. do. . .	15,660 ,,
4 do. do. . .	14,409 ,,
6 do. do. . .	9,036 ,,
10 do. do. . .	27 ,,
12 do. do. . .	10,881 ,,
16 do. do. . .	2,340 ,,
	52,503
To which add pipes laid in 1835, 1836, and 1837,	69,433 feet.
	121,936 feet, or about 23 miles.

Public lamps lighted in the year 1838,—434.

Services laid up to January, 1839,—1,415. Total number of burners at that time, 11,802.

standing the desire of the Trustees to procure meters of American manufacture, they found themselves obliged to resort again to England for this year's supply.

The number imported in 1837 was 343.

The Trustees have given every encouragement to those disposed to enter upon the manufacture of the article in this city, and with a view to encourage private enterprise have not yet commenced the manufacture of meters themselves, although experiencing some inconvenience from the want of a regular supply at home.

The annexed presents a statement of the capital invested and required to complete the extensions of 1837.

	AMOUNT PAID.	AMOUNT DUE.	TOTAL.
On works . .	$54,600 01	$15,604 52	70,204 53
On distribution .	25,859 76	3,400 00	29,259 76
On services . .	11,728 50	3,700 00	15,428 50
On public lamps .	2,146 52	1,741 54	3,888 06
	$94,334 79	$24,446 06	$118,780 85

The Trustees have sufficient means to meet the amounts outstanding, and which it is expected will be liquidated in the course of a month.

THIRD.—*Of contemplated Extensions and Improvements.*

The Works being now considered adequate to the daily supply of from 200,000 to 220,000 cubic feet, the Trustees are however unable at this time to satisfy applications to that extent, because the large 10-inch main, which conveys the gas along Filbert-street from the Works to the centre of the city, appears to be full, and cannot be made to convey a much larger quantity without increasing the pressure upon the gas beyond what appears to be the proper degree.

We have, therefore, reached the point foreseen by Mr. Merrick in his original plan, when it becomes necessary to lay a second large main.

According to that plan, this should be laid in Spruce-street; and the Trustees are convinced of the indispensable

necessity of proceeding, as soon as possible, to lay a 10 or 12-inch main (and the latter would be preferred) along Spruce-street, from Ashton-street to the Delaware. This should be connected with the Works by a 16-inch main laid along Ashton-street. The increased size of the pipes in Ashton-street is intended to admit of their being tapped at all the intersections of the east and west streets by 4 and 6-inch mains, to supply the consumption in all those streets west of Delaware Ninth-street. It would seem desirable, also, to lay a 6-inch and a 4-inch main in Arch-street, for an analogous purpose.

Until this additional main be laid, the Trustees, not deeming it proper to undertake to supply an additional number of customers, were very reluctantly compelled to pass a resolution on the 15th of December last, temporarily closing their book of applications. They trust, however, that the measure so much to be regretted on all accounts, will be but of short duration, and that Councils will soon put in their hands the means of further extending the usefulness of the Works.

The four gasometers will contain 140,000 cubic feet, and might, therefore, with close attention and care, suffice to accommodate a daily consumption of 220,000 cubic feet; but experience proves that it is both safer and more economical to have ample gas room, and to be able to retain at least one day's supply. The Trustees, therefore, conceive that it is essential to have two additional gasometers built, the expense of which is estimated at twenty-five thousand dollars.

The Trustees have for some time past been impressed with the conviction that with a view to accommodate the eastern front of the city, it was desirable that a station should be provided at some low point along the Delaware front, where a gasometer should be constructed, which, being filled by the mains during the day, would afford a steadier supply to the lower parts of the city, than when they have to receive it from mains that are tapped at night in so many places. The construction of this gasometer would cost

about $15,000, independent of any expense attending the procuring a suitable site for it.

The expenditure of the past season for services and meters has been nearly $15,500. An equal amount will probably be required during the present year, should the increased consumption keep pace with that of 1837, of which there is but little doubt if the Trustees should be justified in receiving applications.

Although the establishment is at present in very good working order, still provisions should be made for repairs, which, in the incipient state of the Works especially, are more expensive than they will be hereafter.

The iron roof of the retort-house was so long exposed to atmospheric influences when first constructed, that it had already commenced to rust before the manufacture of gas supplied the tar necessary to the coating of it. From this circumstance, the gas tar did not adhere to it so as to afford the requisite protection, and it now requires very extensive repairs. These, though not unexpected, materially encroach upon the profit account of the Company; but provision has been made out of the present funds to meet this expenditure, which is charged to current expenses, and not to capital.

In like manner, the first gasometer made was, as was stated in last year's Report, very unsatisfactory, and will soon require thorough renovation. The funds for this object are also provided from current expenses.

The constant occupation of the superintendent in attending to the extension has compelled him to postpone the experiments which he proposes to make with clay retorts. Until these are made, the iron ones must be used, notwithstanding their great tear and wear.

FOURTH.—*Of the Finances of the Company.*

The capital had been all expended during the year 1836, with the exception of the thirty-one and a quarter shares, that remained with the Trustees. These could have been advantageously disposed of, had it not been for the restriction in the first section of the ordinance of the 28th

January, 1836, which provides that they shall be sold by auction.

The difficulty of realizing, at any time, the true market value of stocks sold in this manner, has prevented the sale of more than 10 shares, which were parted with on advantageous terms.

The balance remains unsold, to the amount of twenty-one and a quarter shares; and it is respectfully suggested to Councils to remove the restriction, and to allow the Trustees to dispose of them in such manner as they may deem most advantageous.

Of the loan authorized by the ordinance of the 22d of December, 1836, portions have been sold from time to time, as the Trustees required it; and they have strictly complied with the provisions of that ordinance by "setting apart and reserving out of the moneys received by them from the manufacture and sale of gas, the sum of eight per centum per annum on the amount of the certificates issued by virtue of that ordinance, before declaring and distributing among the stockholders any dividend on the profits of the said Works."

This fund amounted on the 1st of January, 1838, after deducting the interest due that day, to $1,327 67. This amount has been invested in the City Gas Loan itself, this being believed to be the safest and best investment that could be made of it.

The dividends heretofore made amount to eight per centum, of which four per centum was declared on the 1st of February, and four per centum on the 1st of August, 1837.

The stock, although promising a fair remuneration to the holders, has not yet paid them even the common legal interest; since the average date of the payment of the several instalments on the capital was the 23d of August, 1835, and they have received altogether but eight per cent.

Another semi-annual dividend will probably be made on the 1st of February next.

The annexed statement A is the cash account of the Trustees from the commencement of their operations to the 1st instant.

The proceeds of so much of the loan authorized in 1837, as has been sold, amount to $109,078 11.

The amount required to pay the sums still due upon the Works, and the other liabilities of the Company, will be about forty thousand dollars, so that there will remain but little, if any, surplus for the purpose of making extensions this year, and to supply the working capital required for future operations. These are estimated by the superintendent as follows:

(In the estimate the materials are taken at the present prices, which are probably as low as they will be in the spring.)

16-inch main in Ashton-street, from Gas Works to Spruce-street, 2,400 feet . . .	$8,500	
12 branches, $300—laying 2,400 feet, $1,200	1,500	
		$10,000
12-inch main in Spruce-street, from Ashton-street to Delaware Second-street, 11,000 feet,	$23,000	
50 branches, $900 — laying 11,000 feet, $4,600	5,500	
		28,500
6 and 4-inch mains in Chesnut and in Arch-streets, from Ashton-street to Delaware Ninth-street—say for each street, $10,000		20,000
Two additional gasometers at the Works .		25,000
A gasometer on the eastern front of the city .		15,000
For services and meters in 1838, estimated as in 1837		15,500
For a working capital		25,000
For extensions of lateral pipes, from time to time, as may be required—say . . .		40,000
		179,000
To which add 10 per cent. for contingencies .		17,900
Amount required		$196,900

Or in round numbers, the sum of $200,000 will be required in order to allow the Trustees to distribute all the gas

that can be made at the present Works, and for which there is a constantly increasing demand.

The Trustees, therefore, ask that they may be authorized to obtain, from time to time, by loan, such additional sums of money as they may require, not exceeding two hundred thousand dollars, in the manner provided for the first loan, and on condition that a similar reservation of eight per cent. shall be made for the purpose of paying interest and creating a sinking fund for the ultimate resumption of the loan.

FIFTH.—*Miscellaneous Observations.*

The manufacture of gas has now attained an extent and a reputation which justify its further distribution as rapidly as may be consistent with a judicious economy.

At first it was used exclusively in stores and hotels; at present its consumption is extending rapidly. Besides the City Hall, State House, the public offices, the market houses, theatres, circus, all the public hotels, and most of the stores, on the line of the pipes, it is used with great advantage and satisfaction in several churches and in private dwelling-houses.

Applications to extend the pipes in streets, where private houses are more numerous than stores, have heretofore been necessarily declined; but should the funds now called for be supplied, it is probable that before another twelve months many private houses will be lighted with it.

Our own experience confirms the statement made by Mr. Merrick in his Report in 1834, that "the extension of gas lights in private houses is not so much the result of its cheapness as a material for lighting, but on account of its cleanliness, its safety, and saving of labour."

The Trustees take this opportunity of stating that the gas has not at any time failed, and that in the few instances in which a temporary deficiency occurred, it has been ascertained to have been caused by a local defect in the internal tubes and burners (which are not put up by the Trustees, but by individual gas-fitters,) or by the neglect of the consumer in not keeping his meter supplied with water. The latter is so

simple a precaution as to require only the most trifling attention; but to remove even the possibility of inconvenience from this source, the Trustees have recently appointed a person to examine the meters from time to time. The defect in the fittings has occurred only in a few instances, and to obviate a recurrence of it the Trustees have lately adopted a few simple regulations, which will, it is hoped, prevent any future disappointment; a copy of which is hereto annexed, marked B.

Several of the insurance companies directed that such buildings as were covered by policies from their offices should, before using gas, be provided with a stop-cock, placed between the external wall of the building and the meter.

The Trustees believe this to be a good precaution, and request the assent of Councils to a new regulation, providing that such a stop-cock shall be placed in all cases, and allowing them to charge the cost of the same to the consumer. They should also be allowed to charge in all cases where services are carried to a greater distance than the usual one of sixteen feet.

In conclusion, the Trustees have to state that Samuel V. Merrick, Esq., the able Engineer, who constructed the first section of the Works, having found that his continued attention to them interfered too much with his private engagements, tendered his resignation, which the Board reluctantly accepted on the 8th of February, 1837. As the extensions were about to be made, the Trustees requested Mr. Merrick to devote occasionally to a general superintendence of the new Works, so much of his time as he should be able to spare, or as might be deemed necessary in consultation with the superintendent. This duty has been performed to their utmost satisfaction, and the Trustees can only repeat here their unqualified approbation of the conduct of that gentleman, and their admiration of the signal success which has attended the Works put up by him.

On signifying his resolution to resign, the Trustees elected as Superintendent of the Works, John C. Cresson, Esq.,

a gentleman of great scientific attainments. No higher praise can be bestowed upon him than by observing, that since he took charge of the Works in March last, he has fully maintained for them the high reputation secured to them by his predecessor; and that the extensions and improvements constructed under his immediate superintendence are, in every respect, equal to the first section; and that the experience acquired in our establishment has been judiciously taken advantage of to introduce valuable improvements.

In behalf of the Trustees of the Philadelphia Gas Works,

R. M. HUSTON, *President.*

Attested.—WILLIAM FENNELL, *Registrar.*

Philadelphia, Jan. 15*th,* 1838.

(A)

Dr. *Cash Account of the Trustees of the Philadelphia Gas Works.* *Cr.*

Amounts received from 21st of March, 1835.			*Amounts paid from 21st of March, 1835.*				
For Capital Stock paid in	$122,375	00	For construction of Works	$120,474	53		
For sales of Loan 1st	109,078	11	For distribution of pipes	71,163	05		
For Bills payable	9,843	33	For Service Meters, &c. $26,550 31				
For consumption of Gas	59,384	31	Received for Do. 5,784 00				
For sales of Coke, Coal, Tar, &c.	6,195	69		20,766	31		
			For public Lamps	5,553	92		
			Capital			$217,954	88
			For Manufacture of Gas, including cost of Coals, Freights, Wages, Salaries, and Rents,			57,313	51
			For Dividends declared			9,750	00
			For interest on Loans			3,983	00
			For Sinking Fund			1,327	67
			Balance Cash on hand			16,547	38
Total	$306,876	44	Total			$306,876	44

Office of the Philadelphia Gas Works, January 1st, 1838.

WM. FENNELL, *Registrar.*

Dr. *Sinking Fund.* *Cr.*

1837.				1837.			
September 6.	To Sundries for amount invested	$330	00	January 1.	By Profit and Loss	$302	67
1838.				1838.			
January 16.	Do. Do.	990	00	January 1.	By Do. Do.	1,019	00
	Balance	7	67			$1,327	44
		$1,327	67	1838.			
				January 16.	Balance	$7	67

(B)

Size of Tubing.	Greatest length allowed.	Greatest number of Burners.
¼ inch.	6 feet.	1 burner.
⅜ ,,	20 ,,	3 ,,
½ ,,	30 ,,	6 ,,
⅝ ,,	40 ,,	12 ,,
¾ ,,	50 ,,	20 ,,
1 ,,	70 ,,	35 ,,
1¼ ,,	100 ,,	60 ,,
1½ ,,	150 ,,	100 ,,
2 ,,	200 ,,	200 ,,

Size of Meters.	Greatest number of Burners.
3 light.	5 burners.
5 ,,	10 ,,
10 ,,	20 ,,
20 ,,	40 ,,
30 ,,	60 ,,
45 ,,	100 ,,
100 ,,	250 ,,

REPORTS

MADE BY

COMMITTEES OF COUNCILS, &c. PREVIOUS TO THE ESTABLISHMENT OF THE GAS WORKS.

The Committee to whom was referred a resolution of Councils directing an inquiry into the expediency of lighting the city with Gas, Report—

That, impressed with the importance of the inquiry referred to them, not only as regards the amount of investment required to carry the project into successful operation, but the moral effect that must be produced by increasing the comfort, convenience, and safety of the inhabitants, the Committee have bestowed great attention, and made minute inquiries, in order to be fully satisfied in their own minds of the propriety of the measure, before recommending any course to Councils in relation thereto.

In the course of their investigation they examined with care the establishments for the manufacture of gas now existing in Baltimore, New York, and Boston. In these cities carburetted hydrogen gas is made from different materials and dissimilar apparatus; and they consequently have been enabled, by comparing the expense of each gas, taking into view their respective illuminating powers and cost of apparatus, to determine the nature of the works which will be found most advantageous in the event of any system of gas lighting being adopted.

These investigations have resulted in a strong conviction

on the minds of your Committee, of the great advantages that would result to the community by the adoption of a system of public lighting, which they believe is far superior and more economical than that now pursued; and in this opinion they are supported, not only by their own observation, but by the experience of every individual at all conversant with the subject.

In arriving at this conclusion, the Committee directed their attention—First, to a comparison between the economy of oil and gas as a means of illumination; Second, to the material from which gas may be produced with greatest advantage; Third, to the objections against gas works as dangerous and offensive; and, finally, to the proper location and probable expense of construction.

To these points, severally, the attention of Councils is requested.

Comparison between Gas and Oil.—In treating of this subject it is not the intention of the Committee to enter into any estimate of the cost of manufacturing gas, for two reasons; first, because in the end any such estimate must prove fallacious, as the expense attending any species of manufacture depends upon many contingencies which cannot be taken into account; and, secondly, it is deemed improper, after the candid manner in which these inquiries have been met by the gentlemen interested in gas works, to expose to public view any calculations tending to affect their interests. It is believed the end may be fully accomplished by comparing the selling prices of the several gases respectively with oil, and showing the state of the concerns of those engaged in its manufacture, so far as it may be proper to make them public.

The Baltimore Company manufacture gas entirely from bituminous coal; the New York Company from resin; and Mr. Robinson, of Boston, a gas from the two materials combined. The several estimates of value, as compared with oil, are, in the judgment of those concerned, as follows, viz.

Coal Gas—specific gravity=400, at $3 33¼ per thousand

cubic feet, is equivalent to oil at 66 2-3 cents per gallon. Resin Gas—specific gravity = 750, $7 00 per thousand cubic feet, is equivalent to oil at 80 cents per gallon. Combined Gas—specific gravity = 600, is equivalent to oil at 70 cents per gallon—or, in other words, 200 cubic feet of coal gas, costing, at $3 33⅓ per thousand, 66 2-3 cents—or 114 feet of resin gas, at $7 00 per thousand, 80 cents—or 140 feet combined, costing, at $5 00 per thousand, 70 cents, will, respectively, give the same light in the same time as one gallon of oil.

It should be borne in mind, in all inquiries respecting the illuminating powers of different bodies, that the quantity of light in the same time must be carefully considered. This remark is made for the reason that the Committee have found this circumstance generally overlooked. Frequently it has been observed to them by consumers, that gas light was quite, if not more expensive than oil; but when pressed upon the subject, they acknowledged that their stores were better lighted, which readily accounted for the increased expense.

In taking the estimate of the comparative value of coal gas as here given, on the correctness of which all sources of information agree, it is very clear that the public lamps could be supplied with gas at a less expense by 33⅓ per cent. than with oil, the same quantity of light being obtained, provided the gas could be purchased at $3 33⅓ per thousand. It becomes therefore a question to be determined by a view of the state of similar works, whether it would be a profitable undertaking to manufacture gas at city cost.

The Baltimore Company, the oldest in this country, and who may be considered the pioneers in gas works, both as to date and variety of experiments, originally constructed works for the manufacture of tar gas. This scheme totally failed, both as a source of profit to the manufacturers, and convenience to the consumers. The gas afforded being too offensive for endurance, these works were abandoned, and new works, for the use of coal, were constructed by an English engineer, on a plan now used in some parts of England. The second set of works have in their turn given place to

others, which produce gas with greater economy, and are now in successful operation. Their gas is of an excellent quality, and notwithstanding the great expense they have incurred in bringing the works to perfection, and, in addition, the circumstance of their gas being burnt (ad libitum) without, in many instances, any restrictions as to the quantity burnt for the price paid, the stock of this Company is 35 per cent. above par, with a surplus fund, and paying 8 per cent. dividends. They furnish 3000 private, and 100 public lamps.

The New York Gas Company's Works were originally constructed for oil gas. Finding the material too expensive, resin was substituted. They, too, have had their difficulties to encounter, and prejudices to overcome. That their gas has forced itself into favour is clearly demonstrated by the fact, that they now light 10,000 private, and 376 public lamps:—under a contract with the corporation of the city to furnish gas for a certain burner specified, at the annual cost of oil expended on each of the residue of the city lamps, and which proves to give about five times the quantity of light that is afforded by each of the oil lamps upon which the price was predicated. The Company are losers annually between four and five thousand dollars on this contract, and yet their stock is 46 per cent. in advance of the par price. They annually lay by a considerable surplus, and pay 10 per cent. dividends.

The Boston Gas Works being private property, of course no notice of their profits can be taken.

If the prosperous condition of the several gas manufactories in this country is not sufficient evidence of the profitableness of the manufacture, a reference to the offers made to former Councils, by men well versed in the routine of its manufacture, may set the question at rest. An individual offered, a few years since, to light, free of cost, all the city lamps within the range of his pipes, in consideration of permission to lay the pipes in the streets.

Being satisfied, therefore, that the manufacture and sale of gas is a profitable business, and at the selling price it is

cheaper than oil, it is perfectly clear that the gain to the city by its introduction will not only be the 33⅓ per cent. difference between oil and gas at that price, but the difference between the cost of manufacture and the price at which it is sold, be that more or less. When, moreover, it is considered that the proportion of gas sold to individuals in other cities is thirty private to one public burner, it is fair to presume that the consumption of gas by the citizens of Philadelphia will be sufficient to reduce the cost of that used for city purposes, so as to materially diminish, if not annihilate, that portion of the now existing tax.

It remains but to make a single comparison of cost before leaving this subject.

During the month of December a careful account has been kept by the captain of the watch of the consumption of oil by one city lamp, an argand burner, with reflector. The result is, that the number of hours it burnt was 235, and the quantity consumed, measuring each filling carefully, was 3 gallons 1½ pint. The number of hours during which, in June, the lamps were lighted was 121, and the average number of hours for each month was 178, or per annum 2,136. The aggregate consumption of oil upon the experiment made would be 29 gallons per annum. No allowance is here made for waste, or for the difference between the freedom of volatilization in the variations of temperature, the experiment being made at a low temperature, when a much less quantity of oil would be consumed than in warmer weather. The same officer reports, that for the common city lamps he delivers to the watchmen 36 or 38 charges of oil per annum, of one quart each, and for the argand reflecting lamps at the same time one gallon for each. The comparison will therefore be founded on a consumption of 30 gallons per annum. The cost, therefore, of sustaining one argand reflecting lamp will be,

36 gallons of oil, at $1	$36 00	
Extra attendance to watchmen, at 50 cents per month	6 00	
		$42 00

Brought forward . . .	$42 00
1 gallon of oil being equal to 200 feet of coal gas, a light of equal intensity would consume 7,200 feet per annum, at $3 33⅓ per thousand cubic feet . .	24 00
Saving on each reflecting lamp	$18 00
The common city lamps consume ¼ the quantity of oil, or 9 gallons, at $1	$9 00
¼ the quantity of gas, or 1,800 feet, at $3 33⅓ . .	6 00
Saving on common lamp	$3 00

In considering the economy of gas one important item should not be overlooked; the Committee refer to the expense and trouble incident to the attendance and cleansing oil lamps, and waste of oil. In large establishments where oil light is used this is an onerous tax, which on the introduction of gas lights will be wholly done away with. The Committee have conversed with several large consumers, who have declared their willingness to pay 50 per cent. additional, rather than be deprived of a light so convenient and so clear.

The want of economy in the consumption of gas in Baltimore has been noticed; the consumers generally pay by the burner, which is defined. Each consumer uses as much as can pass the apertures in the burner, and frauds are committed by enlarging them. Having no motive for economy, the lights are used as long as it may be convenient, and no attention is paid to saving the gas.

In New York and Boston a different system has been adopted, by which the quantity consumed by each individual is accurately measured and charged accordingly. This is effected by an instrument called a meter, which is attached to the service pipe at the entrance of each house; this instrument is of tin, and of a cylindrical form, revolving in a case, air-tight, of the same metal. The inner cylinder, which is composed of four apartments of given dimensions, revolves in water immersed to a point a little above the axis; each

compartment has two openings, one for the admission, and the other for the emission of the gas. As the cylinder revolves by the pressure of the gas, the compartment rising out of the water fills, which displaces the water it contained, while the other descending, refills with water, the gas passing upward through a discharge pipe to the burners. The axle of the revolving cylinder operates upon gearing, to which clock-hands are affixed, indicating on the dial the number of revolutions made, and consequently, the capacity of the cylinder being previously ascertained, the quantity of gas consumed is measured. The adoption of this system tends to the advantage of all parties. The consumer pays for no more than he uses, and consequently burns with as much economy as is consistent with his interest, and the producer is not subject to loss from carelessness or malice. The key of this meter is kept in possession of the manufacturer.

Material to be used.—Various circumstances induced the Committee to select bituminous coal, as a material which may be used with greatest economy in the manufacture of gas. In the first instance, the gas made from it is less expensive; but this advantage is in some measure counterbalanced by the greater amount of investment required for its introduction. The coal gas being the lowest in the scale of illuminating powers, the same quantity of light will require a proportionate increase in quantity of material; of course more extended works for the production and larger mains for conduit are required. Were there no other considerations, a question might arise.

All the products of coal gas are available for some useful purpose. The coke is a valuable fuel, and one for which a great demand will at once be created for manufacturing purposes. Each bushel distilled will produce $1\frac{1}{4}$ bushel of coke, which for manufacturing purposes is equivalent to a barrel of charcoal. The tar, of which one quart is produced from each bushel, finds a ready sale at both the existing works at 3 dollars per barrel; and the ammoniacal liquor, of which the same quantity of coal produces 4 gallons, is purchased

by the chemists at half a cent per gallon. The value of the residuum of each bushel of coal may therefore be estimated as follows:—

1¼ bushel of coke, allowing for waste 20 per cent., will net to customers one bushel at 15 cents	15
1 quart of tar, net	2
4 gallons of ammoniacal liquor	2
	19 cts.

or very nearly the cost of the coal distilled.

On the other hand, resin yields no residuum of any value as an article of sale, consequently the whole cost of the material must be paid out of the sale of gas.

Again:—The production of coal (a staple article of Pennsylvania commerce) is unlimited, and when the improvements now being made are completed, the probabilities are more in favour of a reduction than of an advance in price. The increased demand occasioned by the consumption at the Gas Works would not have the effect of enhancing the value of an article of so vast production as coal.

Resin, on the contrary, is but a residuum in the manufacture of turpentine, consequently its production will be limited by the demand for turpentine, until the price is so advanced as to make it a primary object, in which case the cost of gas made from it would far exceed that of coal gas. It is easy to predict the effect upon the market by the sudden creation of a demand so great as would be required for an article limited in its production and already scarce.

In planning the Works it may be expedient, while the general arrangements are designed for coal gas, to provide for a few benches of resin retorts, having a double object in so doing. A portion of resin gas, mixed with that from coal, will much improve the brilliancy of the light produced. This of itself would not be a sufficient reason, but it is believed that such an arrangement will be conducive to economy, in making use of the oily matter evolved from resin gas to mix with the fine coal and dust now lying refuse on our anthracite coal wharfs, which it is probable would

produce a fuel sufficiently inflammable for the use of the Works, at an expense less than that at which other fuel could be procured.

Objections.—In the investigations of the Committee, their especial attention was called to the only objections of weight that they believed could be urged against the proposed system,—danger from explosions, and the offensiveness of the manufacture to the neighbouring inhabitants.

The first of these objections might almost be dismissed without discussion, when it is considered that the gas itself cannot explode, under any circumstances, without an admixture in certain proportions with atmospheric air, and that such an admixture cannot possibly take place to any great extent, either suddenly or without the knowledge of the workmen. The danger of explosion at the gasometer stations is so remote as not to be worthy of a thought.

The only danger to be apprehended is from leakage in pipes where they are enclosed in air-tight vaults or closets. And even here the very existence of the leak must be detected by the odour of the gas.

In evidence of the entire security which exists against such an evil, it may be remarked that, notwithstanding the immense extent to which the production of gas has been carried both in Europe and America, there has no instance come under the observation of the Committee, in which loss of life has been sustained in consequence of explosions. A Committee was appointed, who, after a patient investigation, and an examination upon oath of every distinguished practical and scientific individual they could find versed in the art, reported against any parliamentary enactments on the subject. The danger from fire, too, is much less in houses where gas is used than oil. The insurance companies much prefer the former risk.

The remaining objection is to the offensive nature of the manufacture, and on this head the community have had great cause of complaint.

The nuisances complained of arise from the discharge of

the residuum and refuse lime-water into the streets and sewers. The coal gas works are less liable to objection on this account, as the residuum is all stored away for sale, leaving the lime-water only to be discharged, the manufactory itself being no more offensive than a foundry or large smith's shop, where much bituminous coal is consumed. The precaution lately adopted at Boston has overcome all difficulty. The lime-water is discharged through an iron pipe into the river, under tide water, and provision made to prevent its return up the neighbouring sewer upon the reflux of the tide. With this precaution no inconvenience is felt. All objections on the score of offensiveness may be overcome by judicious arrangements in the construction of the Works.

Location.—In determining the location of a manufactory in which large quantities of bulky material or fuel are required, the main circumstance to be considered is the facility of placing the material at the Works; and of course it should be located as near to navigation as possible, believing that it would not be judicious to seek a location without the limits of the city. Two sites only present themselves; the one, in Drawbridge lot, the other below the bridge on the Schuylkill. The first of these would in many respects be preferable, but considering the value of the property, the whole of which would be required, it might perhaps be more economical to incur the expense of a transit main to the Delaware front, and establish the Works on the lot bounded by Chesnut, Front, and Beach-streets, and provide on the Delaware front sufficient gasometer room to supply the eastern plane with gas during the night, which had been made and transmitted from the Works in the day-time.

This main would require to be separate and disconnected from the pipes from which the gas is taken for consumption, because it would be so unequal in the several parts of its elevation and depression, that no uniformity of light could be maintained; and if the gas were forced over the elevation in Broad-street with sufficient pressure to discharge it at

Water-street through the ordinary conduit pipes, the leakage, by reason of the numerous openings, would cause great waste. It will therefore be requisite, after preparing sufficient gasometer room at the Works to supply the western plane of the city and store the night's manufacture, to furnish stations at several depressed points on the eastern plane of the city adequate to its consumption. A plan of the city has been prepared, with proposed mains and pipes laid down, as follows, viz. — In Ashton and Water-streets a main of 10 inches diameter in the clear must be laid for the supply of their respective sections of the city, and connected by a transit main of the same dimensions from Ashton-street down Spruce to Dock-street lot, where it is proposed to make the first gasometer station; from thence the Water-street main is to be supplied. The connexions to the Ashton-street main between the Works and Spruce-street to be stopped during the day-time while the transit of gas is effecting. From the Water-street main it is proposed to lay two 6-inch mains up Market and Chesnut-streets to Broad, up Dock-street to Third, and one main of the same size up Walnut and Arch-streets. Two 6-inch mains the whole length of Second-street, and in Third from Walnut north to Vine-street. One 6-inch main in Fourth and Sixth-streets, from Chesnut to Vine-street, and in Fifth-street from Chesnut to Cedar-street. Two 6-inch mains in Broad, from Cedar to Vine-street. In all other streets, two lines of 4-inch, and in all lanes or alleys one line of 3-inch pipes.

By this arrangement of the mains and lesser pipes it is believed that an ample flow of gas may be effected in all parts of the city, and capacity of main sufficient for its regular transmission to the several gasometer stations that may hereafter be required.

In proposing this disposition of the several pipes, it has been the view of the Committee, that although the great extension will very much diminish the income of the Works as taken in relation to its cost, by increasing the investment and expending it in situations where no revenue can

be expected, yet as the construction of these Works will be a great public benefit, increasing the comfort and safety of the inhabitants, the light, so obtained at public expense, should be shed alike on the poor as well as the rich; they therefore have provided for the transmission of gas as speedily as means can be obtained, through every street, lane, or alley, in the city.

Expense of Construction.—In estimating the expense of constructing the necessary Works for the manufacture of the gas, as well as its transmission through the various sections of the city, the Committee have deemed it proper, that no reflections may be cast upon them in future times, to consider them in their fullest extent, and to include Works of sufficient capacity to answer for the purpose of manufacture and distribution of all that will probably be required for a long series of years. In preparing the plans, it would be judicious to make such arrangements as will carry this object into effect, that in the event of their being completed at some future day, they may present a symmetry of appearance and uniformity of arrangement, that will do credit to the city which possesses, and the engineer who constructed them: hence it will be necessary to allot ample ground, and have a general outline prepared for their future completion. In the mean time, if the commencement be in accordance with the plan devised, a very small portion of the Works may be now constructed, leaving the gradual increase to be effected as the demand for gas, and the means at hand for their extension, will warrant it.

The whole plot of ground alluded to will not be more than sufficient for the object, and should at once be appropriated. Before making this estimate it will be necessary to determine as nearly as possible what the extreme consumption will be. This of course must be done upon the longest night in the year, as to meet this the Works must be competent.

The number of lamps now in use (public) is less than 2,300, and are spread over nearly the whole city. They will

not therefore be materially increased; the estimate will be based on 2,500 burning twelve hours, and consuming $3\frac{1}{2}$ feet per hour; *id est*:—2,500 × 12 × $3\frac{1}{2}$ = 105,000 cubic feet for one night's consumption;

Say	105,000
Suppose 12,000 burners (private), each burning from five till ten—five hours, consuming $3\frac{1}{2}$ cubic feet per hour, or 12,000 × 5 × $3\frac{1}{2}$ for consumption = .	210,000
Total number of cubic feet	315,000

To furnish to consumers 315,000 feet of gas in one night, and compensate for waste in its transmission and condensation in pipes, 66 coal gas retorts, with proportionate apparatus for condensing, purifying, and storing, will be required. In determining the cost of these extensive Works, your Committee are guided by a comparison with similar establishments, and by such information as could be gained, without making complete drawings and accurate estimates from them.

Being inclined to give the fullest latitude to every contingency, they are of the opinion that 200,000 dollars will cover the whole expense, including the transit main from Ashton-street to the Dock-street station, together with three gasometer stations, and four gasometers on the eastern plane of the city, but exclusive of conduit pipes.

The expense of laying the pipes for the transmission of gas throughout the city can be determined with considerable accuracy from the experience already had. From the plan laid down, the measurement of the several sizes has been made with due allowance for branches and hubbs, as follows:—The prices are per foot, and including every expense:

11,146	feet of	10-inch main at	$1 95 . .	$ 21,734 70
83,703	"	6 "	1 07 . . .	89,562 21
349,620	"	4 "	0 71 . . .	248,230 20
108,396	"	3 "	0 60 . . .	65,037 60
				$424,564 71

Brought forward . . .	$424,564 71
Add cost of Works as above	200,000 00
2,500 lamp-posts, including lamps and fixtures, at $25	62,500 00
Total expense	$687,064 71

In preparing this estimate the Committee have been careful to avoid deceiving themselves or the Councils as to the eventual cost of the Works, being unwilling to be reflected upon hereafter for having induced the Councils, by imaginary calculations, to engage in any work more costly than they were led to believe; they have therefore placed the estimate on so liberal a footing, that they feel confident the whole work may be executed considerably within that amount.

Several years must elapse before the whole plan can possibly be carried into execution, and it will rest with future Councils to determine whether it shall stop, or to what extent it shall be carried. In the mean time, with the expenditure of less than half of the capital stated, the Works may be completed so far as may be required to convey the gas through the business parts of the city. That portion of the city will yield all the profit that can ever be expected to arise from the sale of the gas, and will of itself be sufficient gradually to extend the pipes to such parts of the city as will remain, and in which the gas will only be required for public purposes. An expenditure, it is believed, of 250,000, or to the extent, 300,000 dollars, will carry this plan into complete effect, provided the Works are not charged with the interest thereon. If the idea suggested by a committee appointed by the last Councils be carried into effect, namely, the construction of these Works out of the income of the Girard estate, the Councils may rest assured that the annual appropriation for light will be for ever extinguished, and one object of the benevolent testator carried into full effect—that of decreasing the burden of taxation. The Committee are unanimously of the opinion, that the Councils have full authority, in Mr. Girard's will, to appropriate the

surplus income of the estate for this purpose, and in this opinion they are supported by the City Solicitor.

In accordance with these views the Committee have prepared an ordinance, the adoption of which they recommend. As the summer is the period of active operation, so the winter is the time for preparation; and as it would be advisable to have the Works in readiness, and sufficient pipe laid to render them available for purposes of revenue before the ensuing winter, the necessity of an early decision is suggested. In preparing the ordinance provision is made for a standing committee on lighting and watching. The object of uniting these two branches of public service under the superintendence of one committee is the intimate connexion which exists between the manufacture and consumption of the gas. Inconvenience has been found to exist in other cities from the public lamps not being under the control of the Gas Company's agent, an evil which it may be as well to avoid.

All which is respectfully submitted.

(Signed by the Committee.)

Philadelphia, 1st January, 1833.

The Committee to whom the remonstrance of sundry citizens against the introduction of gas was referred, having duly considered the several objections urged, concluded their Report in February, 1833, in which they introduced the following abstract from the Report of a Committee of the British Parliament on a similar subject in the year 1823:

"Your Committee are of opinion that the danger likely to arise from gasometers and gas works is not so great as has been supposed, and that therefore the necessity of interference by legislative enactments, pointed out in the Reports referred to them, does not press at the present period of the session.

"It appears that great improvements have taken place

in the apparatus, machinery, and management of gas works since 1814, the date of the Report from the Committee of the Royal Society, which have very much lessened the danger from such works; and that improvements are daily making in every part of them, that must still further lessen the danger necessarily attendant on such establishments.

"The evidence sufficiently supports the opinion, that the risk of accident or danger is but small if the ordinary care and attention necessary in every large establishment is paid by the officers and workmen employed on the premises.

"It is in evidence that carburetted hydrogen gas, usually supplied to the public, is not of itself explosive, but that, in order to render it so, a mixture of from five to twelve parts of atmospheric air, and the application of flame, is necessary; whilst the manner in which the gasometer houses are generally built renders it extremely difficult to form the mixture requisite for explosion, and, consequently, renders the chance of accident remote.

"The danger attendant on the use of gas in the streets and passages appears also to be small, and that it will, probably, by the better management and care of the persons employed in these establishments, be henceforth lessened.

"Your Committee cannot close their Report without expressing their satisfaction that the public have obtained so great and so rapidly increasing a means of adding to the convenience and comfort of society as the use of gas, under due management, must afford; and they are of opinion that, as a means of police, much benefit would be derived from its general introduction to light the streets of this metropolis."

As the remonstrance of the citizens referred especially to numerous accidents which were stated to have occurred in the United States, the Committee considered it their duty to lay before Councils the best information they could obtain on the subject: they therefore addressed a letter to the Mayors of Boston, New York, and Baltimore, of which the following is a copy:

Sir,—The Councils of the city of Philadelphia have appointed a Committee to inquire whether it is expedient to adopt a system of gas lighting in preference to oil, on which subject they have reported.

Doubts have been expressed by a number of respectable citizens of the propriety of the measure on several grounds. Among the most prominent are, the danger from fire to which houses are liable that are lighted in this way, and the great loss of life and destruction of property from explosions where this mode of lighting has been adopted. With a view to elicit, from the highest source of information, facts from which the Councils may arrive at correct conclusions, the Committee have directed me to address you this letter, and respectfully request that you will at your earliest convenience reply to the following inquiries:

Has there been any increase in the number of fires in your city since the introduction of gas, and if so, do you attribute that increase to the gas?

Has there been any instance in which houses are known to have caught fire from gas, and if there has, on what evidence does the statement of the fact rest?

Do you consider the introduction of gas into buildings as more dangerous than the use of lamps or candles?

Has there been any instance within your knowledge of great loss of property, loss of life, or serious personal injury, by the explosion of gas in the works or pipes?

With much respect,

S. V. Merrick,

on behalf of the Committee.

Philadelphia, 18*th January*, 1833.

The replies of the gentlemen to whom this letter was addressed were highly satisfactory to the Committee; and another letter having been written by Mr. Merrick to the President of the New York Gas Company, in which information was requested from a Fire Insurance Company, "as to any difference in risk, or preference between buildings lighted with gas or oil," the opinions of the Presidents of seven different Fire Insurance Companies in that city were obtained, and thus expressed by Mr. Worthington, then President of the Franklin Fire Insurance Company: "I

have the pleasure to state, that upon the first use of gas in this city, the fire companies generally came to the conclusion, that their risks were not enhanced thereby, and premiums were of course not varied. Indeed, it is obvious that the fixed position of the gas lights renders them less liable to communicate to any combustible material than portable lights of either candles or oil lamps."

On the 2nd of January, 1834, a resolution was passed by the Select and Common Councils, "authorizing the Gas Committee to engage a competent person to proceed to Europe for the purpose of examining gas works, with a view of obtaining the best information as to the construction of works, the manner of manufacturing gas, &c." S. V. Merrick, Esq., was selected for this mission, and in December of the same year made the following Report:

To the Select and Common Councils of the City of Philadelphia.

GENTLEMEN,

IN pursuance of a resolution of your body, passed on the 2nd of January, 1834, and of instructions from the Committee charged with an inquiry into the expediency of lighting the city with gas, received on the 18th of March last, the undersigned immediately embarked on his destined mission; and during the course of the past summer has made a careful examination into the various plans and processes employed in manufacturing carburetted hydrogen gas, for private and public illumination, now in use in the principal establishments of Great Britain, as well as a cursory view of the works in Paris, Brussels, and Ghent.

In conducting these investigations, I have to acknowledge the friendly reception I met with from gentlemen connected with gas manufactories, either as engineers or managers, in most places which came under examination, to whose liberality I am indebted in general for opportunities granted for a free inspection of their works, and in many cases for the entire confidence with which their modes of operation and results were communicated.

The gas works which I visited on the Continent being all of English origin, and under English control, I was unable to obtain

from them any information of material value not already derived from original sources which had been brought under previous notice. In the course of this communication, therefore, my observations will be confined to comparisons between systems used in England or Scotland, believing that the purposes of the mission will be fully attained by such comparisons as may there be made.

In preparing this Report I have deemed it my duty, upon reviewing the instructions, rather to take a general view of the arrangements and machinery best adapted to the wants of the city, and to point out the system which appears most conducive to its interests, than at this late day to enter into any laboured argument to prove the general expediency of a measure which has received the sanction of so many years' experience.

Arriving in a country, the capital of which consumed during the past year a quantity of gas equivalent in illuminating power to nearly forty million pounds of candles,—which possesses within its limits and populous suburbs forty-seven stations for making and storing gas, erected by twelve different companies, who have in their construction profitably invested an aggregate capital of near eleven millions of dollars, and whose arrangements are not now sufficient to supply the growing demand, it appeared too late to inquire whether gas as a means of illumination was preferable to any other substance.

If I add to this the universal testimony of the citizens of that metropolis, and of high public functionaries, as to the moral effect experienced by the facility of producing, at a moderate expense, a brilliant light in the streets and narrow passages with which that city abounds, adding to the safety, comfort, and convenience of society, it will not be expected that much time will be occupied in demonstrating what is thus forced upon our attention.

If other evidence is wanting to prove the consideration in which this system is held in Great Britain, I may instance the fact, that during five months' travelling in that country I scarcely ever passed a town or village, to which the material was accessible, that was not provided with this indispensable means of obtaining light, or was in preparation for it; and so great has been the extension during the past year, that all the foundries which came under my notice were full of contracts for the delivery of pipes and retorts.

As far as I have been enabled to collect the history of these small works, they have generally been erected by the owners of real estate as an improvement to their property, and, when completed, leased to

any individual who would keep them in repair, and pay the best interest on the cost.

Believing, as I do, that the formidable objections raised when this subject came under discussion during the past year were entirely refuted by the Report of the Committee, who examined into their truth, and being confirmed in the opinion as to the correctness of the statements made by that Committee, it is sufficient to refer to that document in case such evidence should now be deemed requisite.

In considering the kind of gas works best suited to the wants of Philadelphia, it will be necessary to take a general view of the systems now practised in Great Britain, the materials employed, and the mode of constructing the apparatus for distillation, giving a comparison of the advantages of each plan.

As regards the materials which may be used in the manufacture of gas to the best advantage, enough has been said in the Report of the Committee made to Councils in March, 1832, who carefully investigated this part of the subject, to show how much will be gained by the use of bituminous coal instead of the more costly material heretofore partially adopted in this country and in Europe; and I deem it an argument of no small moment in favour of this mode of lighting, that every material used in the fabrication of gas will be the product of Pennsylvania labour. The bituminous coal from which it is to be made may be drawn from the rich mines now open in the interior of this state; the fuel from the exhaustless beds of anthracite, and the lime for purification, from our own vicinity; and not a lamp will shed its rays over our streets which has not paid a tribute to the internal improvements of the state.

If any evidence be required in confirmation of their opinion, it is to be found in the fact that the use of oil as a material for the production of gas has long since been abandoned in both countries, and the works used for making resin gas; even this material has failed to make a successful competition against the cheaper substance, having finally given way after a long struggle.

The resin gas works of Great Britain have been, or are about to be, converted at a heavy expense into coal gas works, and in New York the Company who are now erecting their works for supplying the upper part of the city have been compelled in part to change their plan and adapt them to the use of both materials.

Believing therefore that coal in great abundance and of good

quality may be had for the supply of the works, my attention will be confined to it as a gas-making material, and to the plans now in use for its manufacture.

The coals used in Great Britain for this purpose are various in their properties and values, but for our present purpose may be divided into two general classes, viz., the Cannel or the Parrot Coal of Scotland, and the soft or bituminous coal, more abundant in England.

The former of these ranks highest for the purpose, containing a larger proportion of carbon and volatile matters, with less bitumen than the soft coal; producing a gas highly charged with olefiant gas, and possessing an illuminating power superior to any other known in the kingdom.

This material is in use in Manchester, Stockport, and some other towns in England, and almost universally in Scotland, yielding gas having a specific gravity nearly equal to resin gas.

The coke from this coal is of but little value in comparison with that produced from the soft coal, being of less bulk than the material from which it is made, and furnishing but a small quantity for sale, after deducting that required for fuel to heat the retorts.

From this material, therefore, but little profit is derived from any product except the gas; but the superior quality of that gas, in connexion with the low price of the material, warrants its use in those works which have adopted it, and the proprietors have been compelled to pay undivided attention to increase the quantity of gas without reference to profit from the residuums.

As in America there is no coal yet discovered bearing any resemblance to this material, it would be useless to dwell here upon the systems used in its carbonization, except as showing the experience of several works, having used precisely the same material on different systems, and in apparatus varying in construction from each other, but bearing a comparison with those used for the carbonization of fat or soft coals.

I shall advert, therefore, to the Cannel coal works, after treating of the plans adopted in England for the carbonization of the soft coal; among which the Newcastle, yielding about thirty-five per cent. of volatile matters, seems to stand pre-eminent in reputation, producing in the usual mode of operating from 10,000 to 12,000 feet of gas per chaldron. Specific gravity from 4·10 to 4·30.

It may be proper here to remark, that although the specific gravity of gas will not give precisely its value or power of illumi-

nation, still, as a general rule, the approximation is so near that I adopt it as an indicator of the value of the gas, for want of a more accurate standard, which may be referred to in general terms.

The various proportions in which the component parts are found incorporated in the bituminous coals of Great Britain, yielding gas of different qualities, and more or less in quantity, add much to the difficulty of comparing the several systems of working with each other. The results of all comparisons must therefore be mere approximations, except where coal from the same mines affords the basis.

To seek, therefore, a series of works in which the same coals were used appeared to me essential for definite purposes, while I continued to confirm my results by observation elsewhere.

The coal I found in most general use was that already alluded to, from Newcastle on Tyne, being preferred in London, and on the eastern and south coast of England, to any other within reach; and as some of these works varied in their modes of distillation, it became for all practical purposes a standard material by which to compare the respective operations of each, diminishing the difficulty of selecting a plan best adapted to our purpose.

The system upon which gas is to be made at the least cost first claims our attention, and resolves itself into three points:

1. The expense of fuel and material for carbonization.
2. The expense in wear and tear of apparatus.
3. The labour attendant upon its manufacture.

This is a subject on which much diversity of opinion exists among gas engineers:—the plan of retort, the duration of the charge, and the temperature at which the process of carbonization is to be conducted with best advantage, are points of controversy among them at this day.

To describe all the plans would be quite useless. I shall therefore confine all observations to those which appear most deserving of merit, and necessary to our present purpose.

The first plan claiming attention is the oven of Mr. King, with which we are familiar at the coal gas works of America; the dimensions being 5½ feet wide by 6 feet long, 18 inches high at the crown of the arch, and 12 inches at the spring, carbonizing about 10 bushels of coal at a heat, or 1 ton in 24 hours.

These ovens are made of thick boiler iron firmly riveted together, with the bottom of the same material set in an arch of brick-work, heated by one fire, the bottom being shielded with fire-tiles to

protect it from the direct action of the flame, with longitudinal flues under it; the draught, passing over the top of the oven, makes its exit in the crown near the front. Some ovens of this description are in use at Liverpool, with cast-iron bottoms, but their value has not been determined on by practice. This plan of carbonization I found nowhere in extensive use, except at the Liverpool Works, constructed by the inventor.

Of the cast-iron retort there are many modifications, varying in dimension and shape with the caprice of the conductor, and in many cases without any definite idea of the principle to be aimed at.

They may be divided into three general classes:

1st. The circular retort, from 12 to 20 inches in diameter, and from 6 to 9 feet in length. This retort is used in Manchester and some other places, in general for the distillation of Cannel or Scotch Parrot coal. It answers for the distillation of a coal which retains its form in lumps, and is advantageous only from the facility with which its position is changed, when partially destroyed by the action of fire on the under side.

2nd. The small or London D retort, so called in consequence of its having first been used by the Chartered Company in London, being still in use at their works, and recommended by their engineer. This retort is 12 inches broad on the base, 11 inches high, and 7 feet long, carbonizing $1\frac{1}{2}$ to 2 bushels at a charge.

3rd. The York D retort, (so called in consequence of its having been introduced by Mr. Outhit, of York,) and the modifications of it, among which I should include the elliptic retort, as having the same general purpose in view. The difference between the London and York D retorts consists only in an extension of surface upon which the coal is spread, the latter varying from 18 to 30 inches in width, and about the same dimensions in length and height.

These cast-iron retorts are set in benches of from two to nine in a set, usually enclosed in an arch of brick-work, heated with one or two fires, arranged with shielding tiles, so as to prevent a direct action of the flame upon the metal; some with ascending, some with descending flues.

To describe the particular mode of setting on each plan would require drawings in detail; a labour entirely uncalled for, as the proper plans will be prepared of the arrangement deemed most effectual.

In addition to these I have found retorts or ovens composed of fire-brick, built in form, or of clay moulded to the shape in the ar

constructed to receive it, varying in dimension and shape from 2 to 4 or 5 feet in width, which will be treated of in the sequel.

The plan of retort, and the system of working to produce the greatest quantity of gas of the best quality, is at present a subject of controversy among engineers, and to form a just opinion requires a careful comparison of the operations of each.

As the whole economy of gas-making depends upon the expense of carbonization, it was an object of much solicitude to obtain from the books at the respective works such statements of their daily operations as would enable me to form a correct estimate of their advantages, rejecting mere theoretic opinions and verbal statements, if unaccompanied by satisfactory testimony.

In giving the general result of these examinations it will not be requisite to record the names of the works, as such a publication would be a betrayal of confidence highly unjustifiable.

These statements have been generally obtained for a short period of time, to avoid multiplicity of figures, but have been compared with the workings for much longer periods, often six and twelve months: the results may, I think, be received with confidence.

The following have been taken as the elements of comparison:

1st. The quantity of coal used for carbonization and fuel.

2nd. The product of coke in weight.

3rd. The product of gas and quality.

By deducting the second from the first we shall have the net amount of material consumed to produce the third element or product of gas in cubic feet, its quality being considered generally.

This mode of comparison has been preferred to the more usual estimate of ascertaining the proportion of fuel used to the coal carbonized; because the latter method is liable to error, as the quantity and quality of the gas is improved by adding to the temperature at which the distillation is carried on, and consequently increasing the amount of fuel burnt.

In this comparative view all residuums, save the coke, are rejected; not because they are worthless, but on account of the great difficulty in obtaining a correct statement of the quantity made, and variation in value of the other residual matters.

The vast quantity of tar and ammoniacal liquor made in Great Britain has rendered them so far unsaleable that the latter is often evaporated under the retorts or flues, and the former accounted of more value as a fuel for heating retorts than as a marketable product. Such residual matters, therefore, in a comparative statement,

do not constitute an item of sufficient importance to affect the result in an appreciable degree, though some difference must exist in the quantity of tar made when very high degrees of heat are used in the carbonizing process.

The system of carbonization which has longest obtained, and which at the present day is in most general use, is to fill the retorts with coal, leaving space for the increased bulk of the coke, and for the insertion of tools for its removal, carbonizing with a moderate heat, and allowing the charge to remain exposed to the action of the fire for six or eight hours.

The opposite to this is to charge the retorts with less coal, or a thinner strata, and to increase the temperature so as to work off all the gas contained in the charge in three, or at most four hours.

By the first mode of operating less fuel is required to carbonize the same weight of coal, and the retorts being subjected to more moderate heat will remain fit for service a longer period of time. It is, therefore, contended by its advocates that the saving of fuel and saving in retorts more than compensates for any advantages to be obtained by the short charge system.

The opposite doctrine is not new, having been held and practised in the early stages of the art, under many practical disadvantages; but the more easy operations on the long charge system have been practised in a majority of the works using the bituminous or soft coal.

The attention of several skilful engineers has of late been directed to an improvement in the quality, and increase in quantity, of gas produced, which they have effected, in a material degree, by operating with high temperatures and a thin strata of coal.

Their practice has been founded upon the following theory:—

That the first products from the distillation of coal, after the water has been evaporated, contains the greatest quantity of olefiant gas, and consequently has the highest illuminating power.

That if this gas be evolved at a high temperature, it carries with it in combination a portion of carbon, which, at a low temperature, would not be disengaged as gas, but would pass over as tar.

That, as the process advances, the proportion of carbon evolved diminishes, while the proportion of sulphur increases.

That, after the first two hours, the quantity of gas and its specific gravity diminish in a rapid grade.

To test the accuracy of this theory certain experiments were instituted, intended to ascertain the quantity and quality of the gas

evolved during different periods of its distillation, varying the quantity charged at each time, the temperature at which it was carbonized, and the duration of the process, so as to embrace a fair comparison of the two modes of working.

The first experiment was made with two York D retorts, 22 inches broad by 7 feet long, charged with 200 lbs. each of Lambton's Primrose (Newcastle) coal, heat kept up to a fair red, and continued for nine hours. The result was that the production of gas, from 400 lbs. of coal (5 bushels), amounted to 1,620 feet, or less than 11,000 feet per chaldron; that four-fifths of this quantity were evolved during the first six hours, and more than half evolved during the first four hours. Specific gravity 4·5.

The next experiment, made with the same retorts, heated to a higher temperature, charged with 140 lbs. each, and worked off in six hours. The gas produced from this charge of 280 lbs. was 1,750 feet, or in the ratio of 18,000 feet of gas per chaldron; six-sevenths of the whole product being evolved in four hours. Specific gravity 5·18.

The charge being then reduced to 120 lbs. to each retort, or 240 lbs. total, was worked off in five and a half hours, producing the same ratio of gas to the chaldron. Eleven-twelfths of the whole product being evolved in four hours; the product in gas evolved after the four hours not being worth the fuel taken to produce it.

By carefully repeating these experiments, and taking the specific gravity at various stages of the process, it was found to decrease in each successive half hour as the work progressed after the second or third trial; while the result, as respected quantity, proved equally in favour of the short charge system.

The result of these experiments clearly establishes the fact, that the greatest quantity of gas and the best in quality may be produced by working a diminished quantity of coal in the recipient at a high heat.

So far, therefore, as quality and quantity of gas produced are concerned, the principles to be followed are,

1st. An extended surface, and thin strata of coal in the retort.

2nd. Rapid carbonization at a high temperature.

From insulated experiments, such as have been detailed, no judgment can be formed on the other points of comparison: although care was taken to note the quantity of fuel used in each experiment, the correctness of the statement cannot be assumed as a guide to continuous work.

To determine the expense of fuel required under different circumstances, recourse must be had to the continuous operations of works using the same material for carbonization, and dividing the amount of fuel into the product of gas made, instead of the quantity of coal carbonized: for this mode of estimation the reasons have been given.

The statements now presented are from works carbonizing Newcastle coal at four and six hour charges. As I could obtain no returns from works using the same coal at eight hour charges, the comparisons will be confined to the first two, which are sufficient for our purpose.

Station No. 1. London D retorts, area of surface 7½ feet, set two to one fire; the lower retort cased in tiles, and the return flue passing under the top retort unprotected; the whole covered with a fire-brick arch, charged every four hours with 1 bushel, or 80 lbs. coal.

Whole amount of coal used for fuel and carbonization in pounds	154,800
Deduct coke made	59,166
Total material consumed	95,636 lbs.

to produce 551,387 feet of gas, or to each pound 5·75 feet. Specific gravity 4·8.

Station No. 2. Retorts and setting the same as No. 1, area 7½ feet, charged every six hours with 1¼ bushels, or 100 lbs. coal.

Whole amount of coal used for fuel and carbonization in pounds	69,520
Less coke made	22,433
Total material used	47,087 lbs.

to produce 222,600 feet of gas, or to each pound 4·6 feet. Specific gravity 4·4.

Station No. 3. York D retorts, setting the same as before, are of a surface 12½ feet, charged once in four and a half hours, 1¼ bushel of coal.

Whole amount of coal used for fuel and carbonization in pounds	25,360
Deduct coke made	8,700
Total material used	16,660 lbs.

to produce 91,550 feet of gas, or to each pound 5·40 feet. Specific gravity 4·70.

Station No. 4. Elliptic retorts, area of transverse section $8\frac{1}{6}$ feet, set seven in a bench, shielded from the action of the flame by fire-lumps, covered with a brick arch, charged with 2 bushels, or 160 lbs. every six hours.

Whole amount used for fuel and carbonization in pounds	105,720
Deduct weight of coke	43,680
Total material used	62,040 lbs.

to produce 308,000 feet of gas, or to each pound 4·8 feet. Specific gravity 4·33.

Station No. 5. York D retort, set same as No. 1, area of surface 13 feet, charged every four hours with $1\frac{1}{2}$ bushel of coal.

Total coal consumed for fuel and for carbonization in pounds	23,600
Deduct coke made	9,240
Total material consumed	14,360 lbs.

to produce 92,500 feet of gas, or to each pound 6·44 feet. Specific gravity 5·10.

It will be here seen that the result of the comparison between the two systems, as illustrated in these five statements, is as follows :—

No. 1.	London D,	4	hour charges,	5·75	feet to pound.
2.	Do.	6	do.	4·60	do.
3.	York D,	$4\frac{1}{2}$	do.	5·40	do.
4.	Elliptic,	6	do.	4·80	do.
5.	York D,	4	do.	6·44	do.

The quantity of gas produced from a pound of material used, and the quality, as indicated by the specific gravity, invariably give the advantage to the short charge system.

It should be observed, that the coke produced upon this system is lighter than by the old plan, and the bulk increased. These points being established, we are next to compare the economy of the plans respectively, taking into view the wear and tear, and the labour required to keep up the supply.

It does not necessarily follow that an increased temperature will create a corresponding increase of wear in the retort, as variable heats have a much greater effect upon them than high heats if they are kept uniform. The results are not so disastrous upon the retorts used in the short charge system as might be supposed, provided care

is taken to keep the temperature the same; but the difficulty of keeping high heats equable exposes the retorts worked on this system to greater risks than by the opposite plan. To determine, therefore, what will be the duration of them is difficult, as experience on a large scale has not yet been had to settle this point; although, in small works, whose operations have been brought immediately under the eye of the engineer, but little difference in duration has been found between the two plans. Still it would not be wise to draw from their experience conclusions, and refer them to works on a larger scale, which must be intrusted to a greater number of stokers, and which cannot be kept so completely under control. In Great Britain the proportion of gas required during the summer months is so small in comparison to the other parts of the year, that during this period a great majority of the retorts are thrown out of service; consequently in a set of retorts, the usual duration of which is eight months, a sufficient number will be saved to do the work of the other four, or summer months; for, except in large cities, the public lighting is entirely suspended during that term, and the private lighting diminished in a great degree.

In a work, therefore, in which the retorts can stand eight months' active service, they will require renewal annually to keep the stock whole. In works operating with six hour charges I have found a better average duration than here stated, and that two complete renewals in three years, being equal to working twelve continuous months, may in general be calculated on.

This duration is more than many works attain, and may be considered the highest average that can probably be allotted to them.

Retorts working eight hour charges often remain in continuous service eighteen or twenty-four months; indeed I have known them thirty. No economy is derived from such long use, because, although the retort will not leak, the product is constantly diminishing, while the proportion of fuel increases from the contracted space in the retort occasioned by the solid particles of carbon which collect on its internal surface. Indeed this obstruction takes place shortly after the working commences, and the incrustation increases so fast that it is doubtful whether there is much saving effected by retaining a retort in service past one season.

But it is needless to go into minute calculation upon this point. If we lay aside the retorts working eight hours, and form the comparison between those working four and six hour charges, we shall

find that the additional duration of the last is compensated for by the diminished number required to do the same work on the first plan, on account of the rapidity of the working, and the additional gas produced from the same material, leaving the wear and tear about equal.

Thus, to make 100,000 feet of gas in twenty-four hours by the six hour system, producing 11,000 feet to a chaldron of Newcastle coal, would require 9 chaldron 4 bushels.

Say 41 retorts each, 2 bushels to a charge, 4 charges in 24 hours.

$41 \times 2 \times 4 = 328$ bushels, at 11,000 feet per chaldron, 100,000 feet.

To make the same gas by the short charge system, at 15,000 feet to the chaldron, would require 6 chaldron 24 bushels coals; say 27 retorts, $1\frac{1}{2}$ bushel to a charge, 6 charges in 24 hours.

$27 \times 1\frac{1}{2} \times 6 = 243$ bushels, at 15,000 feet per chaldron, 101,245 feet.

Thus the number of retorts required to produce the same quantity of gas bear the relation of 41 to 27.

Now if the retorts on the six hour plan require renewing twice in three years, there will be required for that period $41 \times 2 = 82$ retorts. While on the other system, lasting but one year, there will be required 27×3, or 81 retorts.

Thus, notwithstanding the duration of the retorts upon the four hour plan is less than upon the other, when the expense of renewal is divided upon the quantity of gas made during an extended period of time, the difference is unappreciable; while the former possesses the advantage of requiring less space, and less capital in the original construction of the works.

From this statement it is evident that, as the labour must bear a proportion to the number of retorts at work, and the quantity of material to be handled, the advantage is decidedly in favour of the last named plan.

In these remarks reference has been had to cast-iron retorts only; but so far as the amount of production is considered, they refer equally to the oven of Mr. King.

These ovens, it has been observed, are made of malleable iron, and in point of economy in wear and tear have a decided advantage over the cast-iron retort, for the work they are capable of, requiring less fuel than many of the other works.

I should be much inclined to adopt them in preference to the cast-iron, were it possible to work them on the short system.

The shape of these ovens is such as to carry out the principle laid down to the fullest extent, but the extended surface of the bottom renders it impossible to heat them to the requisite temperature without early destruction to their shape, and soon rendering them unfit for useful service; but I am not at all certain that the adoption of wrought-iron retorts of smaller dimensions would not be conducive of advantage.

The high price of iron in this country led me to examine with care into the plans in use, and experiments now making in England and Scotland to carbonize in retorts or ovens made of fire-clay or brick.

The original inventor of these ovens was, I believe, Mr. Grafton, of Cambridge; and one work in Brighton now operates with them successfully. The manager of the station spoke of them favourably; but I could not obtain an exact statement of his operation, nor could I hear the same good opinion expressed elsewhere, though many had tried them. At one station I found two of his ovens in operation, which required as much coal for fuel as for carbonization; but this was accounted for in the thickness of the walls, which had been built of nine-inch brick.

Independently of the high per-centage of fuel required by the ovens of this material, other difficulties occurred in the use of it which almost proved fatal.

In the first place it was found that the clay, unless made very thick, was a material of too little tenacity to resist any undue pressure, especially where the separate pieces were joined together by cement; and that any accident occasioning a stoppage of gas in the pipes re-acted so violently as to burst or injure the retort.

This difficulty was remedied by building stays or ties into the retort, connected with the outer arch. But the evil most difficult to be cured was the tendency to leak at the junction of the cast-iron mouth-piece, and at the joints, owing to the contraction and expansion of the material under different temperatures.

When the retorts are first brought to their heat, time will elapse before the cement in the joints attains the consistency of the other material, and becomes entirely gas-tight; but, while the temperature is kept uniform, little difficulty is experienced when once they have been made tight.

The constant variation in demand for gas makes it incumbent on the manufacturer to vary the number of retorts in action as it increases or decreases. Hence the necessity of letting down the re-

torts, an operation during which the joints, being the weakest part, give way as the brick contracts; and it is more difficult to refill these cracks than to make the original joints with fresh brick and cement. This difficulty has been partially overcome by filling the joints before re-heating with clay cement, and washing them with a mixture of salt and potash, or some other glaze.

To produce a perfect retort of clay, the only desideratum wanting is such a combination of material as will not be subject to change of dimension from any change in the temperature, so that the fires may be let down and rekindled without causing a waste of gas.

To this end Mr. Spinney, of Cheltenham, an engineer of practical knowledge and skill in his profession, has instituted a vast number of experiments, and succeeded by a mixture of fire-clay, pipe-clay, and silex, in producing the desired results.

The Cheltenham Works, under the charge of that gentleman, are provided with retorts or ovens of this description entirely; and the operations of that Company are conducted in a manner highly beneficial to those interested and to the public.

Heretofore single ovens, of a dimension smaller than Grafton's, have been used by him, each heated by one fire; and while the quantity of gas from the coal carbonized is quite as much as would be produced by the same system of working in iron retorts, the fuel account is materially increased—the great saving being in the wear and tear, an item reduced to a very limited amount.

In some new benches erected Mr. Spinney has reduced the size of the retort still more, and set two to one fire, carrying on the carbonization at a lower rate than with the single oven; but this bench has not been in operation long enough to decide whether the saving in wear is not more than compensated by increase of fuel, though, as far as a judgment could be formed, the result was satisfactory.

It should be observed that these works were operating with eight hour charges, and therefore not obtaining all the advantage which might accrue from using an indestructible material.

I am inclined to think, however, that the clay retorts will be found a valuable acquisition to the gas-maker in this country, and am confirmed in this opinion after examining the works of Scotland, in two of which the clay retorts are in constant use with highly beneficial results. Here, as well as in England, immense difficulties have been encountered in bringing them to perfection, but their efforts have been crowned with success.

At the work in Glasgow a fair example is offered of the value of

this material in comparison with iron retorts, in both of which the same species of coal is carbonized.

The principles laid down of working at high temperatures are here carried to a greater extent than any work in England, seven or eight charges being worked off in twenty-four hours, each retort being made to produce near 5,000 feet of gas in that period.

To enable cast-iron retorts to stand such excessive heats at all, it is necessary to shield them at all points with fire-lumps, rendering them as inaccessible to the action of the fire as if they were composed entirely of clay. The result is in this case, that the fuel account is quite as high as with the clay, while the wear and tear is ten to one in favour of the latter material; for, with their utmost care, it is difficult to preserve the iron retorts more than four months, while the clay last from twenty-four to thirty months, and cost far less in construction.

The difficulty which exists in the iron retorts of contracting internally in consequence of the deposit of carbon, has here been remedied in the clay retorts by occasionally leaving the interior in contact with the action of the atmosphere a few hours while at a red heat, the oxygen of which combining with the carbon separates it from the clay surface.

In the work alluded to, the most decided preference is given to the clay retorts, where, as well as at the Paisley Work, which operates with brick retorts on the same principles, the quantity of gas procured from a pound of coal is ten or twelve per cent. greater than in those works using the same material where milder heats, incident to the use of cast-iron, are in practice.

Although, from a careful examination of this subject, I feel persuaded that the use of fire-clay retorts will be found more conducive to economy than those made from any other material in this country (where the price of iron is more than double its price in Great Britain), and that in the event it will be resorted to, yet I am by no means prepared to recommend its immediate adoption.

We have no reason to suppose that our skill will enable us to bring to perfection at once a material which has cost so much labour and loss to experienced engineers, who have for years been endeavouring to bring it into successful operation, and who have not yet brought it to that state of perfection of which it is evidently susceptible.

The immediate success of an infant gas manufactory depends so much upon the first impressions with which it is received by the public, that it would be unwise to abide any risk of failure by stepping

out of the beaten track at the commencement, and I should by no means recommend any change from plans already known and well tried.

It will be ample time to make experiments for the improvement of the process and apparatus when experience has made us masters of the business.

I have therefore selected, as the most suitable for the purpose, the retort described as the York D, of cast-iron, set in such a manner with three to a fire, as will allow of the substitution of the clay retort whenever such a change in the system of operating is deemed advisable.

This retort has been selected, because, under all circumstances, it appears to be the one with which the principles laid down may be carried out with the best advantage, being large enough to give them free scope, and least likely to become distorted by the high heats to which it may be subjected in the process of carbonization.

Having in the preceding remarks attempted to show the system to be pursued for the carbonization of coal on the most economical plan, our attention is next called to the capacity of works required to meet the wants of the city, the mode of construction, and their location, before proceeding to describe the machinery in detail.

To determine the ultimate demand for gas to supply with light an improving city like Philadelphia, is a task for which we can command no certain data, and which, if attempted, must be purely hypothetical.

Before planning new works the usual and most natural course is to make an approximate estimate of the wants of the place, and probable demand; but in most old works that have come under notice, laid out upon such estimates, the demand has increased of late years so unexpectedly that the sites and arrangements are found far too limited for present purposes, and the respective parts of these establishments are in many cases disproportionate to the work required of them.

To plan works on any hypothetical calculation as to eventual demand would without doubt be a fruitful source of error, requiring some parts more extensive than would at present be required, with the risk of their being too small for future exigencies.

Such estimates, therefore, are only requisite for the purpose of determining the size of the leading mains, or great arteries, for the transmission of the gas from the works to the city, which without

doubt ought to be laid of sufficient capacity to meet any contingency; but for the works themselves the estimate of capacity should be confined to the probable present demand, and the establishment constructed complete as a whole to meet that demand, leaving the future wants to be supplied by a similar range of works constructed by the side of the original establishment.

The advantages which may be expected from such an arrangement I apprehend will be,—

1st, That the works may be built upon a uniform and symmetrical plan, with the capacity of each part calculated to meet the wants of every other part.

2nd, That no unnecessary capital may be expended in preparing, on a scale commensurate with future wants, parts of the work now required of a small dimension,—such as purifiers, condensers, &c.

3rd, That in any future increase the fullest advantage may be derived from our own experience, and the advancement of the art elsewhere, in adopting improvements that may occur.

A fourth reason for recommending the plan of a series of minor works has forced itself on my attention while passing through some of the great works of England, viz.: the difficulty of preserving a uniform system of working, and of placing individual responsibility on the workmen engaged in managing long ranges of retorts.

I have scarcely ever seen in a large work a uniformity of heating, or found the superintendent who could form an accurate judgment of the results of any particular mode of operation.

In such establishments a general knowledge of average operations can be readily attained, but nothing definite. It is all-important in a work where so much depends upon the care of stokers, that means should be in the hands of the manager to judge accurately of the operations of each, which can only be effectually done by subdividing the work, having a station meter attached to each division to record the product of every bench of retorts. I have generally found small works doing much better than those upon a large scale.

It is probable that the cost of labour will be a little enhanced during the summer, when full work is not required; but this disadvantage will be more than counterbalanced by the important benefit that will result by being able to keep the operation of the works under the most perfect control.

In selecting a site upon which to construct the works, the choice must be governed by very simple principles.

The specific gravity of the gas being less than that of atmospheric air, the natural tendency of that fluid is to ascend; the level, therefore, of the distributing station should be at the lowest point of the plane to be lighted. Such a location is always desirable, and if it can be obtained should be preferred; but as it is not always practicable, experience has shown that considerable depression may be overcome without affecting in an undue degree the equality of the issue at the burners.

When great descents are to be overcome, distinct stations are deemed necessary effectually to attain this object. I apprehend that, without resorting to this expensive mode of regulation, depressions of 40 feet may be overcome in a district so small as this city.

The evil resulting from inequality of pressure is most felt when the gas is sold by the time of burning, and not by the quantity consumed.

In the former case the consumers are very careless about regulating the issue of their gas, as the expense to them is unchanged, and the cost of the additional quantity consumed by those burners placed on an elevated position is borne by the gas-maker. If, however, the meter system is adopted and carried into universal effect, the consumers take care to regulate their flame to their own wants, and no loss accrues to any one.

Other important considerations in fixing the location are its convenience to navigation, to a coal-market, and to a market for vending coke. All the materials used in the manufacture of gas are bulky, and consequently of expensive transportation. To avoid this additional cost is a matter of paramount importance. It is fortunate that the natural position of the city is such that an easy distribution of gas is compatible with all these objects.

Under the view here stated it is only requisite to enter into an estimate of the capacity of works suitable to the immediate wants of the community, giving a general idea of the probable cost of their construction.

This estimate will be based on the supposition, that the most populous part of the city will first claim the attention of Councils, and that provision for 4,000 public and private lights will probably be sufficient to meet the demand for two or three years, divided in the ratio of 300 public, and 3,700 private burners. In estimating the capacity of the works for the supply of this demand, the greatest quantity of gas required in any one night must be the basis of calculation.

Say 300 public lights burning 13 hours, at 4 feet of gas per hour, 300 × 4 × 13	15,600
3,700 private burners, average time of burning 4 hours, at 4 feet per hour, 3,700 × 4 × 4	59,200
Total gas required in one night, cubic feet . .	74,800

It has already been shown that the retorts recommended will carbonize one and a half bushel of coal at a charge, which at six charges in twenty-four hours makes a total of 9 bushels of coal to each retort.

How far we may be successful in obtaining a coal which will yield a quantity of gas equal to the Newcastle coal, is yet to be determined; but I feel warranted in saying that there will be no difficulty in obtaining a material to produce 12,000 feet of gas to the chaldron, and shall therefore estimate the produce of each retort at 3,000 cubic feet.

To insure against accident and loss in distribution, there will be required a bench of thirty retorts to produce this quantity; and I recommend that the works be constructed on that scale.

In stating this proportion of public and private lights, it should be observed that the ratio is likely to diminish after the pipes pass into streets less occupied for business, until the gas is generally introduced into private houses.

In estimating the cost of the station here described, it must be observed that the data are of the most general character, because, until the location is fixed, the works laid down in detail upon plans, and a knowledge had of what walls, levelling, wharfs, &c. are required, no accurate estimate can be given.

It is sufficient for our present purpose to say, upon a comparison with similar stations in England, and making due allowance for difference of cost in the two countries, that the station here noticed will not exceed 35,000 dollars, and probably come much under that sum. This is exclusive of mains to convey the gas into the city, or effect its distribution when there, but includes the retort-house, gasometers, and all other apparatus necessary.

After taking a view of the carbonizing process, a brief sketch of the machinery required to prepare the gas for use and distribute it over the city, will close this part of the subject.

After leaving the retorts, the gas passes through a large pipe termed the hydraulic main, in which it deposits a part of the tar and

ammonia which flow into their proper receivers, and itself goes to a vessel called the condenser.

The process of condensation first claims our attention, and on the judicious selection of apparatus for this purpose will depend not only the ready purification of the gas, but the prevention of an accumulation of offensive matter in the street mains.

The general impression appears to have been, that the only requisite to insure a perfect condensation of gas is a reduction of temperature; but it would appear from some circumstances that more is required, and that the process is effectually completed only by bringing the gas into contact with cold solid substances. In some of the works in Scotland this principle is carried out to an extreme length, and their condensing apparatus is arranged so as to filter all the gas through vessels filled with "fern," "oak twigs," "stones," or any other substance, the effect of which is to separate the particles of gas from each other during their passage, and bring them in contact with the substances through which they pass. So far as observation leads to a correct opinion, it would appear that works in which a reduction of temperature alone is regarded, the condensation is but imperfectly completed; but when means are taken to bring the gas in contact with solid substances by filtration, or a constant change in the direction of the conduit, the effect is made evident by a more perfect condensation.

In works which have come under notice, the condensers are made in every variety of shape which suited the views of the constructor, without, however, in many cases keeping in mind these principles. While it would be a useless task to describe each variety, they may be divided generally into two classes,—the air and the water condensers, or those in which the temperature is reduced by the action of the air, or by immersion in water.

The water condensers are usually either pipes immersed in water, or oblong boxes of cast iron, communicating at their ends, and extending from 200 to 700 feet in length; or in some cases, upright pipes, connected at the top and bottom, surrounded with a cast-iron tank filled with water.

The air condensers are usually a series of upright pipes, connected at the top and bottom, having vents at the lower bends for the discharge of the condensed matters, tar, &c.

The general principles upon which this part of the apparatus is to operate being known, its form may be varied to suit the circumstances of the place in which it is to be erected; and that form

which is the simplest, taking up the least space, and which costs the least money, is undoubtedly to be preferred, provided it will perform its functions with equal certainty. As the air condenser comes under all these conditions, I give it the decided preference, taking care to vary its form from the mere series of pipes, so as to increase the surface with which the gas may be brought in contact.

The first impression natural to a view of this condenser is, that during the heat of summer the temperature of the atmosphere may be so high as to disable it from producing the desired effect; but this is not the case, for by the aid of a small stream of water sufficient to keep the outside of the pipe moist, an evaporation takes place which reduces the temperature as low as is desired, while at all other seasons the object is gained by an exposure to the air alone.

The usual mode of construction is to erect the pipes on the north exposure, protected from the direct rays of the sun, and this appears in many respects preferable to the water condenser.

The tar and other condensible substances having been deposited from the condenser into their proper receivers, the volatile products, or gases, flow to second vessels, called purifiers.

The volatile products from the distillation of coal are various in their nature and properties, being valuable for the purposes of illumination, in proportion as the pure olefiant gas and carburetted hydrogen can be separated, and preserved distinct from the other products.

To separate these valuable gases from the others, numerous plans have been put in practice successfully, but all with the same agents.

The heavy or condensible matters have all been partially disposed of; but there still remain in solution some portion of ammonia, and all the gaseous products which cannot be condensed.

To effect an entire deposition of ammonia requires the presence of water, for which it has a strong affinity, while lime has been found the best material for depriving the gas of sulphur, the impurity held in the largest quantity, and of the most deleterious quality. The effect produced by its presence during the combustion of gas is to send forth a suffocating odour, and to tarnish metallic polishes whenever it comes in contact with them.

Water and lime therefore being the substances best adapted to separate the impure matters from carburetted hydrogen gas, it naturally followed that a solution of lime in water was first used

for the purpose of purification, and vessels of various constructions were rendered subservient to this purpose, by passing the gas through the liquid, keeping the lime in solution by constant agitation, and changing the water whenever the application of gas to paper saturated with acetate of lead or nitrate of silver was found to produce a change of colour: experience soon taught the operators that it was requisite to wash the gas in three distinct changes of water to free it entirely from its impurities.

So far as regards the economy of material only this plan has undoubtedly the advantage, because the particles of lime, being held separately in solution, may each individually be brought into contact with the gas, and be saturated with impurities; an effect which cannot be produced so perfectly when the lime is not held in solution, owing to the amalgamation of many particles together, which protect each other from the action of the gas.

This process, however, must in some degree prove a nuisance, from the difficulty of getting rid of so large a quantity of liquid material impregnated with nauseous vapours.

To avoid the disagreeable effects upon persons residing in the vicinity, by whom complaints were often made, recourse was had, in many cases, to a discharge of this refuse underground into neighbouring rivers or streams; but when this was deemed objectionable, extensive cesspools were resorted to, from which the liquid was gradually conveyed under the retorts and evaporated. By any mode the discharge of this fluid is troublesome, and requires great care to prevent its becoming offensive to those residing near the works.

The disagreeable nature of this residuum led Mr. Phillips, of Exeter, to propose the purification of gas by means of dry lime, and to construct the proper apparatus for its use. The plan proposed by this gentleman, with some modifications, has obtained precedence very generally in Great Britain, and is now adopted, except in some of the larger works, which still adhere to the original plan of wet lime.

The original expense of material by the dry lime process may generally be considered as double that which is incurred by the wet lime process; but this cannot for a moment be considered, when placed in connexion with the entire freedom from nuisance of which the dry lime process is susceptible.

It has been said that the presence of water is necessary to absorb the ammonia. The process of Mr. Phillips was called dry lime, in

contradistinction to the lime cream or wet lime plan, while, in fact, the lime is saturated with water to a consistence that would adhere if pressed between the fingers.

In some cases this admixture of water, together with the condensation, was deemed sufficient to free the gas from ammonia; but the process being imperfect, recourse was had to washing the gas in clear water, previous to condensation, with success. It has been found advisable to pass the nascent gas from the hydraulic main through a reservoir of pure water, which takes up much of the ammonia that would otherwise be lost, producing a highly saturated liquor of value, and materially assisting the process of condensation.

The dry lime purifiers consist of a series of large square boxes of sheet iron, having projections placed on the sides, to receive sieves or wire gratings, upon which lime, slaked and moistened, is laid in strata of 1 to 3 inches thick, as lightly as possible, so as to allow the gas freely to percolate. At the Paris works a stratum of fern or moss is spread on the sieves under the lime, to assist its free circulation.

Considering therefore that the works may, if properly arranged, be freed entirely from all offensive or disagreeable odour by the adoption of the dry lime system, it appears to me far better to overlook the difference between the economy of the two plans, and to adopt that system in any works to be erected in this city.

In the construction of gasometers many improvements have been made of late years, tending to reduce the expense and simplify their action.

The constructors have at last discovered, that as gas may be safely retained in a vessel no stronger than a silk balloon, there is no occasion for building gasometers strong enough to retain steam, and the heavy iron and wooden framings with which they were formerly encumbered are dispensed with. No ribs or braces are now inserted, except such as are required to keep the vessel in shape until filled with gas.

The capacity of gasometers must, of course, vary with that of the works. It is not generally the custom, but I think it judicious, to have nearly as much gasometer room as the retorts can fill in a day. In many instances I found the disadvantage from being cramped in gas store-room very manifest. In the depth of winter, when the demand for gas is at its maximum, the want of an adequate supply in store is often severely felt; and in some cases recourse has been had to working extra benches of retorts for the night only.

The consumption of fuel during the day to keep up the heats for night work must necessarily be very disproportionate to the object gained.

The necessity of letting down retorts during the suspension of public lighting upon moonlight nights, is an evil which can only be remedied by an excess of store-room. Indeed, in many places, where the capacity of the gas-holder is too limited, it is found expedient to keep the public lamps lighted during moonlight nights, rather than incur the expense of letting out and re-heating retorts.

It is believed, therefore, that true economy points out the policy of a full share of store-room notwithstanding the expense is considerable, especially in a new and growing work, where extensions may be looked for very soon.

The store-rooms being determined, the capacity of the gasometers must approach the quantity already named of 74,000 feet.

To avoid accident, it will be judicious to have this capacity divided into two vessels, which will fix the size at 50 feet diameter by 18 feet deep, vessels well proportioned and of convenient dimension.

Gasometers of this size do not require counterbalancing, as the pressure upon the gas to sustain the whole weight will be less than the resistance due to a column of water 3 inches high, a pressure quite convenient when the weight of the gasometer is not used to regulate the flow to the burners.

The usual method now adopted to equipoise large gasometers is to insert cast-iron frames on the top of the tank, with guide rods and friction rollers to preserve a steady motion up and down, allowing the vessel to play upon the gas within.

This plan is far preferable to the old plan of suspension from the centre of the gas-holder crown, which was liable to the objection of creating a flickering in the lights whenever the vessel was agitated by external causes. Another method of suspension has lately been put in practice, which answers even better than the guide rods for keeping the vessel steady. This is, to suspend at three points, with chains tending to and terminating at one point, by a triangular frame of wood-work; to these chains connected a counterbalance was hung.

The plan of triangular suspension has one decided advantage in a climate liable to falling or drifting snow. The weight of snow falling on one side of the vessel will not affect its perpendicular position, while, with the guide rods, it might affect the free play of the gas-holder.

On the whole the triangular suspension appears preferable, and the expense is not much more than the guide rods, the weight required being merely sufficient to keep the gas-holder steady.

The practice of enclosing gasometers within buildings, which from their size must entail a heavy expense on the establishment, has long since been abandoned, and they are now universally placed in the open air, even in the northern part of the island, where the climate is quite as severe as that in which we are placed. There may perhaps be seasons in which the extreme severity of the weather will affect the water in the tank, but in general the constant supply of fresh gas, at a temperature much above freezing point, will prevent any accident from impeding the free motion of the gasometer, while temporary precautions may be taken, if ordinary means should fail.

The liability to frost is the only objection which can be raised against the exposure of gas-holders in the open air, and the ease with which that evil is guarded against precludes the necessity of incurring the heavy expense incident to the construction of buildings.

There is another advantage, however, which ought not to be overlooked. I allude to the impossibility of any serious accident occurring from the explosion of gas in vessels placed in the open air.

It has been shown on a former occasion, that the only time a gasometer can be put in a condition liable to explosion is during the act of expelling the air and introducing the gas in the first instance, but that afterwards, if a rent or hole be made in it, the only evil that can result is a loss of gas; for the weight of the gasometer will cause the gas to flow out of such hole, and entirely prevent the admission of atmospheric air, to create an explosive mixture within. It is clear, therefore, that if the gas escape by accident or design, the loss in the open air is the sole evil to be apprehended, as an explosive mixture cannot be formed outside of the gasometer, there being no building to confine it. The danger from explosion is an evil the fear of which has long since passed away in all places where gas is in general use. It is there looked upon as an idle chimera.

The nature and properties of gas are now so well understood, and the precautions to prevent accident so well known, that notwithstanding the immense number of works existing at this time, a disaster is of rare occurrence; and when one does happen, the injuries are not extended, as formerly, beyond the damage done to the vessel itself where the explosion takes place.

The tanks to contain water, into which the gas-holders are inverted at some works, are cast-iron plates bolted together, with a bottom of same material, but more generally of brick or stone, having the bottom well puddled before the pavement is laid, and the outside round the wall secured in the same way.

The latter method is preferable, whenever the nature of the ground will admit of such a structure, on account of the greater economy in the construction; and as the brick is a worse conductor of heat than iron, the water is less liable to be affected by frost. In such cases it is usual to sink the tank entirely beneath the surface, thus keeping the gasometer as low as possible.[4]

Having disposed of the gas when made in its store-houses, we have to consider the mode of distribution to the consumers, and the regulation of the pressure so as to insure an equal flow at the burners, points which materially affect the value of the works as a source of public convenience.

The gas is conveyed through the streets in mains or pipes of cast iron, to determine the proper size of which has heretofore been a difficult task, and one which has proved a fruitful source of error and vexation.

To avoid the heavy expense incident to laying down great mains, engineers have often erred on the other extreme, and contented themselves with pipes far too small for the wants of the public; an error which has in some cases led to a useless expense in laying mains unnecessarily large.

Unfortunately, there are even at this day no fixed principles known respecting the flow of aeriform fluids[5] which will guide us surely in determining this point; but we must be guided by the experience of others, applying as nearly as possible their practice to our circumstances.

Before entering upon this subject, it is proper to determine the quantity of gas which will be required to pass the leading mains in a given time, and the location of the works from which the mains are to be laid.

The first reply as to the quantity of gas required must be a mere assumption, for no one can prophesy the extent of the demand.

In Great Britain, it has in growing towns almost invariably ex-

[4] The accident which recently occurred at the Ratcliffe Works, London, where the gasometer tank (being an old brewhouse vat) burst with the weight of water, shows us the importance of sinking the tank underground, to prevent the possibility of such a disaster.

[5] This desideratum is supplied by the Formulæ in 'Tredgold on the Steam Engine.' Weale, London, 1838.—Ed.

ceeded the most sanguine calculations, and we are not likely to be behind-hand in appreciating an improvement, when the value is once understood.

I cannot assume, however, a demand of less than 20,000 lights, including public and private; suppose for the eastern front of the city 14,000, and for the western front 6,000, consuming an average of four feet per hour.

To supply the eastern front, (dispensing with gasometer stations,) will require to be passed in one hour $14{,}000 \times 4$, equal to 56,000 ft.

Western front, $6{,}000 \times 4$, equal to 24,000

Total consumption in one hour in cubic feet . . 80,000

In estimating the size of the mains, it is requisite to know the location of the works, because, if they are to be placed on the eastern front either above or below the city, it is clear that the mains must be of a capacity sufficient to pass the whole quantity within the city limits; but if the location formerly selected be still adhered to, on the western front, then the part of the city between the works and Broad-street may be supplied direct from the works, while the main need only be of a capacity to pass that portion required for the eastern front.

By this means Broad-street will be the point from which the draught on the main will commence, and to which the pipe must be of sufficient capacity to convey the whole quantity required as fast as it is consumed on the eastern front of the city.

By ascertaining the delivery of gas through mains in such cases as I have been able to make observation, I have found one instance of a six-inch main, extending the same distance, in which a pressure of six-tenths of an inch was ample to deliver the gas at a velocity of 10 feet per second. Taking into consideration the difference of friction in a pipe of such dimension, and in one the capacity of which will be sufficient for our purpose, we may feel quite safe in laying a main which will pass the required quantity at the same velocity, or even something less. The discharge through the main alluded to being 7,000 feet per hour at that pressure, or one-eighth the quantity stated before, the main, according to this rule, must be eight times the capacity, or 17 inches diameter; but as the rubbing surface or area, in proportion to the quantity passed, is so much less in the latter than in the former, I should not hesitate to reduce the size to 15 inches diameter, believing that the proportional diminution will be compensated for by the difference in the friction.

In this I am confirmed by reference to another instance, where 23,000 feet per hour are passed five-sixths of the distance through a main 10 inches in diameter, which would give the size required to pass 56,000 feet per hour, by the same rule, 15⅝ inches diameter: this example shows a decrease of friction in greater ratio than in the length of the pipe.

Whether this main of so large dimension should be laid at once or divided into two, of half the capacity each, may be hereafter determined when the plan of distribution comes under final consideration; it is sufficient for our present purpose to know the whole size which will be required.

The capacity of this main has been considered without reference to any assistant station for storing gas or regulating pressure.

It will be recollected that, on a former occasion, the Committee of Councils deemed it necessary to appropriate a station on the eastern front for this purpose, and designated the public lot in Dock-street as a suitable position. In doing this, they certainly acted with sound judgment, believing that the regulating station there would have great effect in preserving an equal flow of gas from the burners in all parts of the city; and it is quite possible that a resort to a regulating station on the eastern front may, in the event, be found not only useful but necessary. As, however, there seemed to be a strong objection among many citizens to such a disposition of that lot, I took some pains, by comparing the situation of this city with others, to ascertain whether the descent from Broad-street was likely to affect the flow to such a degree as to render an easy regulation impracticable, and now feel satisfied, that if the mains are of ample size, no difficulty will arise in distributing from works on the Schuylkill without any auxiliary stations whatever.

If experience shall testify to the correctness of this opinion, a very heavy expense in stations will be saved. It is possible that a difficulty may occur on the eastern wharfs, which being the lowest point may be affected by unusual draughts from above. The only evil to be apprehended is, that as there will be an excess of pressure on the upper burners of four-tenths of an inch over those on the lower level, the size of the apertures in the burners will require to be varied to meet the difference in the rapidity of flow; an inconvenience of no great moment, as it will affect principally the burners below Front-street, where more than half the depression takes place.

It is not, therefore, deemed expedient to take any measures to

provide for the regulation of pressure beyond what may be accomplished at the manufactory, until experience proves the necessity.

The mode adopted in some works for regulating the flow to the burners, is by taking off or adding to the weight which counterbalances the gasometer. But this is a clumsy and laborious plan, and one likely to prove defective, unless the gas-holder is nicely poised with compensating weights. Instead of this arrangement, the conical valve has been substituted, which, by being closed or opened, regulates the quantity of gas flowing from the gas-holder through the exit pipe by changing the size of the opening.

This valve is sometimes opened by hand, but its regulation by the judgment of the workmen does not in all cases answer the desired end, for if a number of lights are suddenly extinguished, the additional pressure on the pipes causes an excess of flow through all the remaining burners; thus, although long experience enables the workmen to regulate with tolerable certainty, yet errors and loss of gas will constantly happen.

To remedy this evil a self-acting governor has been put into use, which consists of a small gasometer, to which is attached the stem of the conical valve. This gasometer is counterbalanced to the weight required to force the gas to all the burners. Any change in the consumption of the gas operates at once to raise or depress this gasometer, and of course regulates the flow by closing or opening the conical valve. Thus, with a self-acting governor, the flow and pressure upon the mains is regulated with great nicety to the exigences of the moment, requiring only that there shall be more weight upon the main gas-holder than upon the smaller one.

The plan for laying pipes, as usually practised, is perfectly well understood here, differing from water-pipes only in one particular; that is, a regular grade of elevation and depression must be preserved, in order to give a descent for the flow of condensed water (which sometimes accumulates in the pipes) to certain points where it may be received into suitable receptacles, and removed, otherwise an obstruction in the flow of gas might occur.

These recipients are called syphons, or, more properly, condensed water-boxes, and are to be provided at every point of depression.

The mains require to be laid out of reach of the frost; in this climate from 18 to 24 inches below the surface. They are usually laid on each side of wide streets, or, if narrow, one row in the middle is ample, the openings or trenches being made and closed on

the same day, so that the passage of the street is never materially impeded to the inconvenience of travellers; so slight a trench being made that the earth is easily rammed in, and the pavement relaid without waiting for the natural settlement of the earth.

A method has been partially adopted lately which I think far superior to the old mode, in all cases where the pipes are laid over solid ground. By this plan the hubb of the pipe is bored, and the small end turned, each with a very slight taper. The two ends of the pipe, being covered with a mixture of white and red lead, are entered, the small end into the hubb, and driven home with a mallet. The joint thus made is perfectly tight, and the taper so slight that no contraction by change of temperature will render it subject to leak. It is plain that this mode of making joints can only be carried into effect in straight lines, or with slight curvatures; in all other cases the old plan of lead joints must be resorted to.

Where the lines are straight, as in this city, great facility is presented for using the bored and turned joints, which are undoubtedly preferable to lead joints wherever they can be introduced.

The service pipes from the street main to private meters are sometimes made of small cast-iron tube of three-fourths or one-inch diameter, but more generally of malleable iron or lead. The use of malleable iron for this purpose has been almost universal, but it has been found that whenever it comes into contact with ashes, gravel, or sand, it is acted upon and destroyed in ten or twelve years, while in clay no such difficulty is experienced.

The extreme ductility of lead, which is often used, renders it objectionable; being liable to short bends, in which water may lodge and obstruct the flow of gas. To obviate this, lead pipe is sometimes laid in grooved brick, which effectually overcomes the evil, while the expense is enhanced beyond that of iron pipe.

For internal tubing lead or tin is often substituted in place of copper, of which metal the small tubes were formerly almost universally made.

It has been found that the hard solder joints of the copper tubes were apt to crack in the bending, the cracks being almost imperceptible, but still sufficient to cause an escape of gas and an unpleasant smell. The tin or lead being too ductile to crack, answers the purpose exceedingly well in all places where the pipes can be supported in a straight line. The apparatus for internal fittings, burners, &c., are as various as the taste of the maker or consumer

may desire. Samples and drawings of most of those made at Birmingham are in my possession, together with the prices of every article appertaining thereto.

After thus taking a view of the most approved processes of manufacturing and distributing gas, there remain several points to which, by the instructions, my attention has been directed; among the most prominent are the nature and disposition of the residuums left from the carbonization of coal.

The only residuums which will be available are the coke, the ammoniacal liquor, and the tar.

For the coke, there is no doubt an ample market will be found. The high price of charcoal, for which it is a substitute of value, both for the use of founders and for culinary purposes, insures for it a ready sale, the price bearing a proportion to the cost of the coal from which it is produced.

The ammoniacal liquor is useful for the manufacture of sal-ammoniac, and sells for a small price in Baltimore, where there is a manufactory of that article. The produce of a chaldron of coals is from 20 to 30 gallons, but the liquor need not be considered of much value here for some years, or until a sufficient quantity is produced to make it worth manufacturing; for the cost of transportation to Baltimore would make that market of little avail to the works in this city.

The last residuum is the tar, which, in many ways, is of value.

It will sell in its raw state for a fair price; but when the quantity is considerable, a good profit may be derived from it by extracting the naphtha, now an article used to some extent in the manufacture of gum elastic, which leaves, after distillation, about half its bulk of concentrated tar, more valuable than in its original state. Of the process of manufacturing the naphtha I have obtained a description. Under all circumstances it is extremely valuable as a fuel for heating the retorts, three gallons being estimated, for that purpose, equal to a bushel of coke.

The consumption of tar as fuel, in connexion with an equal quantity of water, is practised in some works; and the advantages derived from this combination being doubted, have elicited much spirited controversy during the past summer: to this plan my attention was called during a visit to Mr. Rutter, the inventor, at Lymington. It is the usual custom in most gas works not conveniently situated to a market for tar, to consume their product by conveying it through a tube upon the red-hot bed of fuel on the grate

bars. This process, from the quantity of smoke discharged, and the deposit of solid matter on the other fuel, gave clear evidence of the imperfection of its combustion, and that but a small quantity was made available for the purpose of heating the retorts.

To give the burning tar, in which the carbon is in excess, its due proportion of hydrogen for the production of flame, and oxygen for its support, Mr. Rutter introduced a portion of water, by the decomposition of which a complete combustion of the tar was effected, and the whole of its heating properties made available.

Without taking any part in this controversy, I may be permitted to say, that in no works in the kingdom which came under notice was there any thing like so perfect a combustion of the tar as in those where this process was used, and I had a fair opportunity of comparing the economy of the heating process with and without its use in the same works, which gave decided evidence of the saving effected by the plan of Mr. Rutter.

The prices at which the residuums are sold being dependent entirely on local circumstances, vary so much that no useful purpose would be accomplished by detailing them. In some works the price of coke is fixed from time to time to cover the price of the coal used to make it, and the other residuums are considered of no value for sale. In others, on the contrary, the coke is quite unsaleable, and consumed as the only means of getting rid of it. At some works, too, the refuse lime is sold for prime cost as manure, being considered, from its strong impregnation with ammonia, as being improved in quality for that purpose; in other places, where lime is not valued as manure, this product is but refuse.

For the value of these residuums we must refer to our own circumstances, and I am justified in saying that the ammoniacal liquor will be of little moment for some time to come, but that the lime, tar, and coke will produce valuable results; indeed, for the latter, an offer has already been made for more than the works will supply.

In disposing of the gas, when made, two modes are adopted: the one by meter or measure; the other by jet, or burner.

The latter method is open to extensive frauds, and the effects have been severely felt by those companies who have been unable to change the system. The quantity of gas which will flow through the aperture of a given burner to produce flame of a given height being ascertained by experiment, and also the aggregate number of hours during a year for which light is required, a contract between the parties is made, and the jet furnished.

If the consumers would all adhere to their contract, and if the pressure in all parts of the town were uniform, no difficulty would arise; but whenever a customer raises the flame higher than his contract admits, or burns more hours than allowed by his agreement, he not only defrauds the manufacturer, but injures all customers who do not take such advantages; because the manufacturer, to obtain the cost of his gas and his profit, must enhance the nominal price per thousand, requiring the honest customer to pay the same as he who consumes twice as much as he is entitled to: the correct customer is therefore paying for light surreptitiously obtained by his neighbour.

The evils of this system are so severely felt, that some companies do not receive more than one half the value of their gas taken at its sale price, which they are obliged to keep up, to the cost and disadvantage of the honest consumers.

To avoid this evil, an ingenious mode of measuring gas was contrived in the early stages of the art; which, though liable to some objections, has been gradually improved, until at this time all difficulties are in the main obviated. This instrument is called the gas-meter; and consists of a hollow metal drum, revolving in an air-tight case, filled to a certain point with water: this drum is divided into four compartments, each having two openings, one for the exit, the other for the entrance of the gas. As the drum revolves, one division fills with gas as the opening ascends out of the water; while, at the same moment, the opposite division descends, and gas is forced by the water out of the opening to the burner.

The cubic contents of each division being accurately measured, it is clear that the quantity of gas contained in the drum, and which passes out during one revolution, must be known. This revolving drum acts upon wheel-work attached to indicators, which point, on a watch-dial, the number of revolutions, and of course the number of cubic feet that have passed through the meter during the time it has been operating.

The meters are usually examined every three months, and the gas used during that time ascertained. The more completely to exemplify the action of this instrument, I have obtained, through the politeness of Mr. Crosley, the maker, a model in glass, which is now on its way from London: by an examination of this model, its construction will be more perfectly understood.

It will be seen that the accuracy of this measurement depends upon the position of the water-line, which must be kept at a uniform

height. From want of attention to this circumstance, errors will occur; but the internal arrangements are such, that an error cannot extend far without discovery, in no case exceeding five per cent., and that in favour of the consumer.

The greatest obstacle to the success of the meters has been the decomposition of the material composing the internal drum, by the action of the gas, or some of its impurities, while stationary. I have seen meter drums, made of sheet tin, corroded into holes in five years, which, until discovered, recorded false measurements.

After countless experiments, Messrs. Crosley, of London, have discovered an alloy, which is not acted upon by any product evolved from coal, and the use of this composition appears to render the meter an instrument of such accuracy, that it may be depended upon, and should be universally adopted.

Another instrument has been invented in this country, called a dry meter, because it is used without water, which would be an advantage, all other things being equal. This instrument I have not seen, and of course can give no opinion as to its merits.

The price at which gas is sold in Great Britain varies rather with the amount of competition and cost of production, than with any reference to the expense of lighting by other means.

The gas companies appear to be in far greater dread of rival establishments than from oil or candles. Indeed the latter do not, at this late period, give them a moment's thought; for so many advantages are found to accrue from the use of gas in all situations where fixed lights are admissible, that little impression would be made on the sale of it, even if the price of other light were reduced below that of gas.

In Scotland, where greater attention has been paid to the quality of the gas, it is now the usual light in private houses, as well as in more public situations. The best houses in Edinburgh are thus served, and the consumption of gas is fast increasing.

The extension of gas-lights in private houses is not so much the result of its cheapness as a material for lighting, as on account of its cleanliness, its safety, and saving of labour; and contrivances are constantly being made to obviate the inconvenience of having stationary lights, the only obstacle to its universal introduction.

In England it has heretofore been confined, in the main, to public streets and buildings, shops, churches, &c., but its use in private houses has begun to spread rapidly, as more care is taken in the purification. In London especially, its introduction into private

houses has been very limited,[6] for the companies have rather retarded than urged its adoption, finding more profitable consumers elsewhere, who kept pace with their means of supply.

Within a short period the price of gas has been very materially reduced, varying now from 8*s*. to 12*s*. per 1000 feet, with a scale of discounts for large consumers by meter, proportioned to the quantity used in the year.

To compare the cost of lighting by gas with that of lighting by oil might be difficult upon satisfactory data, because the comparisons at the works there have been made universally with candles. The fine sperm oil of our market is comparatively little used in England, and is retailed at from 6*s*. to 6*s*. 6*d*. the gallon. For public lighting (where gas cannot be had), Greenland or other common oils are used, which sell by wholesale at 1*s*. 9*d*. to 2*s*. 3*d*. per gallon, or an average of 50 cents. This is the imperial gallon, which contains one-fifth more than the wine gallon used here for the same measures. This oil is retailed at 2*s*. 6*d*. to 2*s*. 9*d*. per gallon, and is used for common purposes of lighting. The greater consumption (exempting gas) is in candles of various kinds.

In my endeavours to procure a comparison between the cost of lighting by the two systems, I was fortunate in procuring such a statement as may be considered satisfactory, inasmuch as it is the result of a series of experiments made to show the difference between the illuminating power of gas, made in different parts of England, referring each to a candle as the standard of comparison; the result being given during the last summer, in evidence before a Committee of Parliament, on the application of an oil-gas company to change their works for the manufacture of coal gas.

This statement may therefore be taken as authentic, and referred to our own case.

The results being an average of the quantity of gas made in ten manufactories, which by comparison of shadows was found to be equivalent to 100 pounds of mould tallow candles (burned clear), of six to the pound, 9 inches long, was 2477 feet.

Say 2477 at £3 per thousand (here)	7 43
100 pounds of candles, at £10·50, cost . . .	10 50
Difference in favour of gas . .	£3 07

or near 30 per cent. This is the saving, under the supposition that

[6] It is now extensively used both publicly and privately, and of a superior kind.—Ed.

the candle is all consumed or made available, and always gives the same clear light.

The prices here stated are the retail prices; but it must be remembered that the gas is measured out to the consumer, and burned as fast as it is measured; consequently, he receives the benefit of all that he pays for, leaving the loss of all leakage between the works and place of consumption to fall upon the manufacturer; while, on the contrary, the loss and waste incident to the consumption of candles fall upon the consumer, and cannot be estimated at less than 15 per cent.

Again, during all the period of burning gas, a clear undiminished light is produced, while any light having a solid material for a wick must diminish in brilliancy the longer it continues to burn.

Taking into view all circumstances, it must be admitted that the use of gas possesses advantages which can belong to no other means of illumination.

It may here be proper to give some general idea of the amount of capital required to carry into execution the works as here described, which, for reasons already given, must be mere approximations:

The works, as before stated, will not exceed . . .	$35,000
Considering for the moment, that the works will be located on the Schuylkill, north of the Permanent Bridge, and that the leading main will be divided into two, having the aggregate capacity of a main of 15 inches diameter, one now laid will cost	20,000
Pipes for distribution, in all 5 miles, say 3 miles, of 6-inch, at $3·25 per yard	11,444
Three miles of 3-inch, at $1·80 per yard . . .	9,504
	$75,948

If to this sum be added the expense incident to walling, levelling, and wharfing the lot, construction of public lamp-posts and lamps, with a floating capital necessary to keep up the supply of gas, we may consider that a capital of 100,000 dollars is quite ample for the works, as here described. As this sum will include the expenses incurred by enclosing the property, laying one-half the great main, and a considerable proportion of the larger pipes of distribution, we may safely conclude that the second division of the works will not cost more than two-thirds this amount.

In conclusion, I beg leave to suggest, as the result of my examinations on this subject:—

1st. That all information which has come into my possession, either in Europe or in this country, has tended to confirm the opinion that the proposed system of lighting by "gas" will be found preferable to any other, as regards economy, safety, and convenience.

2nd. That a "gas" manufactory judiciously constructed, and managed with skill and economy, cannot fail to return a handsome profit to its constructors.

3rd. That the art of gas-making has so far advanced at this day, as to place within our reach such information as will enable this city to entertain the measure with a feeling of perfect security as to the result.

4th. That the objections to the measure, and the fears expressed by many valued citizens on a former occasion, are either totally groundless, or very easily obviated, and that the effects which will be produced by a judicious execution of the measure will be beneficial, both in a moral and pecuniary point of view.

5th. That the improvements made within a few years render it an easy task so to construct the works as to avoid all danger from explosions, or inconvenience from the offensive nature of the process, or residual matter connected with the manufacture of gas.

6th. That the works be constructed upon a moderate scale, commensurate with the immediate wants of the city, and made complete; but that land sufficient for the increase of the works should be appropriated for their extension, to satisfy the demand in all parts of the city, and that the mains or pipes be laid of such capacity as to insure their aptitude for any future demand.

All which is respectfully submitted.

S. V. Merrick.

December 11, 1834.

Note.—At a meeting of the stockholders in the Philadelphia Gas Works, held on the 22nd of January, 1838, the following resolution was unanimously adopted: "That the Trustees be hereby authorized to appropriate the sum of six hundred dollars to be expended on the purchase of one or more pieces of plate; to bear such inscription expressive of the approbation of the stockholders as they may think proper; to be presented to Samuel V. Merrick, Esq."

The Committee, to whom was referred the item of unfinished business in relation to lighting the city with gas, presented the following final Report on the 26th December, 1834:

"The Committee have not been able, after all their inquiries and reflections on this subject, to arrive at any other conclusion than that contained in the Reports of all former Committees that have been charged by Councils with the consideration of this subject: viz. *That it is expedient for Councils to introduce this mode of lighting the city.*

"If any thing could be necessary, in addition to the facts formerly reported to Councils on this subject, to satisfy the minds of the timid and sceptical, abundance is found in the able Report of the agent lately returned from Europe. So universal is the practice of lighting by gas becoming on the continent of Europe, but more particularly in England and Scotland, that not only are the large cities, but many of the villages, and even some of the turnpike roads, illuminated by this means; and in our own country nearly all the principal cities are pursuing the same course.

"Philadelphia, confessedly the best adapted, having every possible advantage that nature and art could confer for the purpose, and owning too all the materials for its manufacture, —she, who possessed every inducement to take *the lead* in this great modern improvement, doubts and fears even *to follow* her sister cities.

"Believing, as the Committee do, that Councils cannot longer hesitate on this subject, they now present an Ordinance for the erection of gas works to light the city, to be constructed on a limited and economical plan, embracing the most modern improvements in the art."

(Signed by the Committee.)

[The Ordinance for the construction and management of the Works was enacted by the Select and Common Councils of Philadelphia on the 21st of March, 1835; and, as appears by the second Annual Report of the Trustees, a portion of the city was lighted with gas on the 10th of February, 1836.]

RESERVOIR DAM ACROSS THE SWATARA, PENNSYLVANIA,

CONSTRUCTED BY THE UNION CANAL COMPANY.

(Plate No. XIV.)

THE following description of this important Work is taken from the Report of WILLIAM READ, Esq., President of the Union Canal Company.

The Managers adopted a plan furnished by Canvass White, their chief Engineer, and commenced operations in October, 1828. The work is located in a narrow part of the gorge through which the Swatara passes; the width of the pass at this place is 430 feet.

The dam is divided into two parts, each constructed on different principles: the part on the western side is of crib-work, filled in with stone, to which is added a backing of earth; the other, which connects it with the eastern side, is of stone and earth. The crib-work measures 200 feet across the stream, and 40 feet in perpendicular height: the timbers are 10 by 12 inches square; those at the base are of white oak, and the superstructure of white pine laid at right angles, forming squares of from 6 to 8 feet from centre to centre, firmly trenailed, filled with stone, and strongly fitted against the mountain on the west side, which furnishes an excellent abutment of solid rock. The east side of the cribs is supported and confined by a stone abutment laid in hydraulic cement, which rises to the height of 48 feet, or 8 feet higher than the cribs.

The apron in front of the cribs is formed of white oak plank. The cribs extend up-stream 110 feet, with a backing of earth extending in the same direction 110 feet more,

making the base 220 feet up the stream by 200 feet across the same.

The second part, viz., the embankment of earth and stone, reaches from the stone abutment to the east side of the gap, a distance of 230 feet, and extends at the base 260 feet up-stream, and 60 feet wide at the water surface; the east side of the embankment rests against a natural abutment of rock in the mountain; the embankment rises 2 feet higher than the stone abutment, and is 50 feet high. The whole has been executed in a substantial manner.

The sluice-gates, twelve in number, are of cast iron, each comprising a surface of 2 square feet, are connected with pieces of yellow pine timber, extending several feet above the level of the water, and can be raised or lowered by means of screws. The sluice-gates and machinery are surrounded by a strong frame-work to guard the whole from the injurious effects of ice-freshets and floating timber. The sluice-house is connected with the western shore by means of a light bridge, raised beyond the utmost height of the water in the reservoir, so that the gates may be regulated at every stage of the water.

The water from the reservoir passes through a stone lock of 10 feet lift; the reservoir when filled forms a lake covering a surface of nearly 800 acres, and contains about 600,000,000 cubic feet of water, affording a navigation of 6 miles extending towards the coal mines. The dam cost 22,000 dollars.

TWIN LOCKS ON THE SCHUYLKILL CANAL AT PLYMOUTH,

MONTGOMERY COUNTY, PENNSYLVANIA.

PLATES Nos. XV. XVI. exhibit this Work. These locks were completed in April, 1834, and are the first of the kind erected in the United States. They were designed by and constructed under the superintendence of EDWARD H. GILL, Civil Engineer.

The foundation is rock, and to prevent leakage through the seams, which were numerous, the bottoms of the chambers were covered with a layer of hydraulic mortar 6 inches in depth, and a space extending 12 feet above each mitre sill was covered by a double floor of inch boards firmly secured to the rock, and rendered perfectly water-tight. In preparing the pits and foundations, about 3000 cubic yards of rock were removed, most of which lay below the surface of the water in the river.

The side walls are 8 feet on the bottom and 5 on the top, receding by three offsets or steps of 1 foot each; the centre wall is 12 feet in thickness, and the height from the foundation to the top of the coping is 17½ feet.

The walls are faced with hewn sandstone procured in the vicinity of Lawrenceville, about 26 miles distant, and conveyed to the work in boats. The top, bed, and joints of each face stone are cut the same distance back that it measures in height on the front. Headers or bond stones 4½ feet in length are placed 10 feet apart throughout each course, and the courses vary in height or thickness from 12 to 20 inches. The backing is composed of large hammer-dressed limestone laid close, and grouted with a composition of hydraulic lime and sand. The face stones were laid in

hydraulic cement of superior quality, manufactured in the vicinity of Reading.

The lock-gates are constructed of white oak timber; the heel and toe posts are 10 by 14 inches square, the bars or girths 8 by 10, except the upper and lower ones, which are 10 inches square. The gates are planked with 2-inch yellow pine planks. The wickets or valves are 2 feet 8 inches long by 18 inches deep, and are formed of cast iron, and move vertically, being opened and closed by a rack and pinion secured to the lever beams.

The mitre sills are formed of white oak timber 15 inches wide by 12 in depth, and are secured to the rock by iron bolts 30 inches in length, with fox wedges. (See Plate XVI.)

BAY OF DELAWARE AND THE DELAWARE BREAKWATER.

(Plates Nos. XVII. and XVIII.)

THE following description of the Delaware Breakwater is compiled from the Report of a Board of Commissioners to the Secretary of the Navy, which was approved by the President of the United States in February, 1829. The commission was composed of Commodore Rodgers, U. S. Navy, Brigadier-General Bernard, U. S. Engineers, and William Strickland, Architect and Engineer.

After an examination of the lower part of the Bay of Delaware, but two points in that broad expanse of waters were found suitable for an artificial harbour, the roadstead under Cape May, and that under Cape Henlopen. The shallowness of the former, the danger and difficulty of access, arising from its proximity to the extensive breakers called the Over-falls, as well as its remoteness from the main ship-channel, were deemed conclusive objections against its adoption. Cape Henlopen roadstead presenting none of these disadvantages, and facilitating by its location the chief objects in view, was selected as the most suitable site for the work. The same location was recommended in a former Report, dated July, 1823, by Commodore Bainbridge, U. S. Navy, and Brigadier-General Bernard and Lieut.-Colonel Totten, U. S. Engineers.

The anchorage ground of Cape Henlopen roadstead lies between the southern shore of Delaware Bay and the seaward end of an extensive shoal called the Shears: this shoal makes out from the Delaware shore, at and near the mouth of Broadkill inlet, about five miles west-north-west of Cape Henlopen. The opposite curvatures of the main land, and of the Shears, comprehend the roadstead.

It appears from surveys and soundings made under direction of the Board,—

1st. That the distance between the seaward end of the Shears and the Bay shore exceeds 2 miles.

2nd. That a line drawn from the Cape to the western end of the Shears leaves to the west between it and the curve of 24 feet depth, a space of more than 3 square miles.

3rd. That this curve runs close to the Cape shore, but leaves it gradually as it advances to the west: at a point 1200 yards west of the Cape, it approaches the shore within 150 yards, and at a point 2000 yards from the same Cape, it is at a distance of 400 yards from the Bay shore.

4th. That in assuming a curve of 18 feet depth for the termination of the Shears, the eastern end of this shoal presents over it a depth of water varying from 8 to 18 feet.

5th. That the average rise and fall of tide is 4 feet 8 inches, the highest spring-tide 6 feet 8 inches, the average summit elevation 5 feet 8 inches, and the highest tide known 9 feet.

This roadstead is exposed to all winds from east to north-west, round by the north. It is besides represented as being often obstructed by floating ice, at the breaking up of the river and bay. On this latter point it must be remarked, that the currents of both ebb and flood-tide set constantly in a direction parallel to this portion of the Delaware shore; and that while the former brings the ice from above, the latter causes its accumulation in the roadstead, by retarding its course down to the sea.

With regard to the winds blowing in the roadstead, the north-east and the north-west are the most violent, and both are on our coast the most prevalent, during the season at which a safe anchorage is most needed. The north-east comes from the sea, and the north-west blows freely through the chops of Delaware Bay. The Shears are not sufficiently shallow to moderate the action of the sea raised by these winds; and the Cape May shore is too far off to afford any protection against the effect of the northerly winds.

The objects to be gained by an artificial harbour in this roadstead are, to shelter vessels from the action of waves,

caused by the winds blowing from east to north-west, round by the north; and also to protect them from injuries arising from floating ice, descending from the north-west.

It appears that even the curvature of the shore west of Cape Henlopen does not afford a spacious anchorage sheltered by the land, from the winds blowing from east to west, round by the south. Indeed, a line drawn from the Cape in a westerly direction would leave between it and the curve of 24 feet depth, a superficies of only about one-tenth of a square mile. But by inclining this line to the north a greater space would be obtained, which would be protected from all winds south of this line produced. An obstruction erected along such a line would shelter a space inside of it from the waves raised by the winds blowing from the points above mentioned. But veering still more towards the north, the space open to the effect of winds west of north would be proportionally increased: for instance, should it incline so much as to assume a position directed to the north-west, the space inside of it would become entirely open to the action of the waves from the north-west. Thus, while the line in its former position would not cover a surface of sufficient extent, it would, in the latter, leave too much of the space open to the north-west. Hence, a line has been assumed intermediate between the two preceding, as reconciling the advantage of space with that of shelter. It runs from east-south-east to west-north-west, and affords between it and the curve of 24 feet water, a space with a mean breadth of 600 yards, sheltered from all winds. An obstruction raised in a straight line would check the action of the waves, but would not protect the anchorage from floating ice. It must, therefore, be rounded off at its western end, in order to deflect the descending mass. An ice-breaker will at the same time increase in the harbour the space sheltered from the north-west. Its direction has been assumed west and by south, forming an angle of 146° 15′ with the direction of the Breakwater.

The entrance of this artificial harbour will but seldom be used by vessels descending the river and bound to sea: its

main purpose is to provide a safe refuge for vessels from sea, designing to ascend the river, or seeking shelter during stormy weather.

The entrance will be located, therefore, to the east of the harbour, where it will be accessible during all winds from the sea. Its width must be sufficient to afford a free passage to descending ice floating along the shore; besides, it is desirable that the volume of water running through the entrance should provide the ebb-tide with a momentum sufficient to counteract the effect produced on the Cape shore by the flood-tide. Indeed the latter, by setting from the south, washes the sea-shore south of the Cape, and causes an accumulation of sand to the seaward of it, which forms the shoals and breakers called the Hen and Chickens.

The projecting part of the Cape is represented from the same cause as making gradual approaches toward the north. The current of ebb-tide, stronger generally than that of flood, has probably hitherto counteracted the effects of the latter, and arrested the advance of the sand deposit towards the north. It is therefore of importance that the ebb-current should be preserved in its present course, and whilst the assumed line of direction of the Breakwater does not disagree much with the direction of the current, the opening or entrance between this line and the Cape shore must be calculated for the passage of a large body of running water, the velocity of which would be rather increased than diminished, on account of the acute angle formed by the work and the shore.

These considerations led the Board to recommend for this entrance a width of 500 yards, measured between the eastern end of the Breakwater and the curve of 24 feet depth. A greater width would have increased the space within, so as to expose it to the north-east wind. Besides this main entrance, it was thought advantageous to keep another open at the western end of the work; and with this view it was recommended to detach the ice-breaker so as to leave a passage 350 yards in width between it and the main work.

By such an arrangement a commodious entrance will be

obtained, and the space within the harbour will be increased. Care should be taken that the eastern end of the ice-breaker should shelter the inside of the main work from the north-west. These two entrances open to the east and to the north winds, which blow very seldom on our Atlantic coast, not more, it is believed, than twelve or fifteen days throughout the year.

Such is the location, and such the general outline, which the Board recommended for the work under consideration. As to its extent, 1200 yards are allowed for that portion of it destined to perform the office of a breakwater; and 500 yards for the part designed more particularly to act as an ice-breaker, making the whole length of the two 1700 yards.

The preceding results were used as guides in laying out the work, which was done in the following manner:—A line is drawn tangent to the extremity of the Cape, at high water, and in the direction of west-north-west. A point taken on this line at a distance of 1000 yards from the point of tangency will determine the eastern extremity of the interior line of the top of the work. The western extremity is situated on the same line, 1200 yards distant from the eastern. Having thus laid out the interior line of the top of the Breakwater by producing it 555 yards further, a point is obtained on the interior line of the top of the ice-breaker. A line drawn through this point at an angle of 146° 15′ will coincide with the interior line of the top of the ice-breaker. The eastern and western extremities of this line are obtained by laying off distances of 272 and 228 yards respectively.

This delineation will shelter a space of one-sixth of a mile from the waves raised by winds from north-west to east round by the north, and a space of $\frac{7}{95}$ of a square mile from the waves caused by winds from north-west to north-east round by the north.

These spaces are measured between the work and the curve of 24 feet depth; that comprehended between the work and the curve of 18 feet depth, and sheltered from the waves raised by the north-east wind, will be $\frac{7}{70}$ of a square mile.

It remains now to determine the transversal section of the Breakwater, and the arrangement and size of the materials to be used in its formation.

With respect to these objects, upon which the solidity and durability of the work so essentially depend, it must be acknowledged that theory and mere speculation are utterly incompetent to fix, within precise limits, the degree of resistance to be given to a work exposed to so many and such incalculably violent efforts of the sea. But valuable inferences may be deduced from experimental results afforded by the construction of similar works in Europe, and described in an able paper presented to the French Institute by M. Cachin, General Inspector of French Civil Engineers. Thus the stupendous works erected at Cherbourg in France, and at Plymouth in England, have been resorted to as guides in the investigation of the leading principles upon which the Breakwater under consideration should be constructed. A cursory view of these two works becomes necessary to elucidate the subject.

The road of Cherbourg is the only one possessed by France on the channel; its projecting situation and its proximity within 70 miles of the southern shore of England render this road vitally important to the French navy. But its entrance between Pelée Island and Querqueville Point is no less than 4½ miles wide, leaving the bay entirely open to the stormy winds from east to west round by the north. It was this opening which was to be covered by a breakwater, leaving two entrances, one to the eastward between Pelée Island and the main, the other between the western end and Querqueville Point.

The work planned to fulfil the object in view was formed of two lines, presenting to the sea a very obtuse angle, and having together a length of 2⅔ miles. The depth of water at the lowest spring-tide here is 46 feet, and at the highest 69½ feet. This work was commenced in 1784, was interrupted during the French Revolution, but was afterwards continued with energy from 1802 to 1813.

If the road of Cherbourg is of the highest importance to

France, that of Plymouth is probably of equal importance to Great Britain; as, among other advantages, it enables her to assemble at one point the fleets destined to watch the movements of her neighbours in the roads of Brest and Cherbourg; added to which, the connexion of the road of Plymouth with an extensive naval arsenal makes it a matter of much consequence that it should be rendered perfectly secure.

The works at Cherbourg fully answering the purposes for which they were erected, and demonstrating their importance, the Government of Great Britain caused the erection of a breakwater to be undertaken in the road of Plymouth, which was accordingly commenced in 1812.

The road of Plymouth is sheltered from east to west round by the north by the mountains of Devonshire and Cornwall: its entrance is three miles and a half wide, lying open to southerly winds. The configuration of the shore has permitted the location of this work far inside of the entrance, and has thus procured the great advantage of having the Breakwater exposed only to the action of waves raised by winds from south-east to south-west, round by the south. The work consists of a straight line, bent at the two ends towards the interior of the road. The whole length is nearly 1,500 yards; the depth of water at the lowest spring-tide is 36 feet, and at the highest spring-tide 54 feet. This work is considered as completed. It leaves between its extremities and the shore two entrances; the eastern 900 yards, and the western 1,550 yards wide.

This breakwater, like that of Cherbourg, has for its transversal section a trapezium, the basis of which rests on the bottom, whilst the summit line forms the top of the work: the two other lines are the sides of the work, that seaward having a greater slope than the other.

At Plymouth the interior slope has an inclination of 57 feet altitude to 90 feet base, making an angle of 32° with the horizon. At Cherbourg this slope is of 45° inclination; and, since it has stood firmly under an altitude of more than 70 feet, it may be inferred that at Plymouth the interior slope

might also have been kept at 45°, which would have saved the filling up of the space comprehended between the actual slope and that of 45°.

The Board was therefore of opinion, that as the Delaware Breakwater must be 18 feet lower than that of Plymouth, and 30 feet lower than that of Cherbourg, there should be no hesitation in adopting the slope of 45°.

Respecting the width at the top, the work at Cherbourg is 55 feet, and that of Plymouth 30 feet; both being measured at 3 feet above the highest spring-tide. But when it is considered that these two works, and more especially that at Cherbourg, are higher and more violently battered than the Delaware Breakwater can be, since it will be partially sheltered by the over-falls and the shears,—that the latter work will be struck principally by a rising mass of water only 5 or 6 feet high, which is the difference between the two tides, whilst at Cherbourg this altitude is 23 feet, and at Plymouth 18 feet; and, finally, that as the work at Plymouth has been most severely tested in its solidity, 30 feet may be considered the maximum width for the top of the Delaware Breakwater. Twenty-two feet ought, however, to be tried during the construction of the first portion of the work, in order to test the power of the waves, and lessen the expense as much as prudence will permit.

It remains now to determine the inclination of the exterior slope of the work, and the elevation of the top above the highest spring-tide; both very important points, and requiring the most careful investigation. Indeed, the former will have to receive all the efforts of the sea, and should be calculated not only to resist but to evade their violence; while the latter must be sufficiently high above the surface of the water to insure to vessels at anchor a safe shelter during the prevalence of extraordinary tides and tempestuous weather, and to secure the interior of the harbour from fire-ships. With regard to the exterior slope, it seems to have been contemplated at Cherbourg, when undertaking the work in 1784, that the base of this slope should be three times its altitude. The projectors of the work were led to

this conclusion by observations made on inclinations affected by waves on sea or river shores, acting on materials of stone; but, during the prosecution of the work, experience demonstrated that it belonged exclusively to the variable and incalculable effects of the sea itself to fix irrevocably not only the inclination of the slope, but also its very shape.

At Cherbourg, as at Plymouth, experience has taught, that if human power was able so to heap up materials as to fill up such a space in the deep, it required the agency of tempestuous waves so to dispose of them as to secure their permanent stability. On this score it would seem that the results obtained at Cherbourg from vicissitudes in 1812 were but partially known to the able projectors of the Plymouth Breakwater. Indeed, the base of 180 feet of that work, and its altitude of 57 feet, have received precisely the same ratio as that which the action of the sea had fixed between the base of $228\frac{53}{100}$ feet, and the altitude of $72\frac{30}{100}$ feet of the work at Cherbourg. The surface of the former work having been assumed to be a plane, while at Cherbourg the efforts of battering waves have produced a curvated surface, it is hence to be apprehended that at Plymouth it may become necessary, in progress of time, to add new materials to the lower part of the slope.

The Board, anticipating the progressive effect of the sea, recommended, if not exactly the curvilinear line of the Cherbourg profile, at least to adopt it for the profile of the Delaware Breakwater, so that during the construction of this work a similar result might be kept in view.

The slope herein submitted has been framed out of the following facts and principles afforded by the Cherbourg Breakwater.

1st. The part above the highest spring-tide having been for a short time battered by the waves, which had lost by their ascension a portion of their momentum, received from the action of the sea an inclination of nearly 2 feet base to 1 of altitude.

2nd. The part comprehended between the highest and lowest spring-tide is exposed, during the time of its rise

and fall, to the greatest violence of the waves. Thus permanently swept by the sea, this portion of the slope has received an inclination of 11 feet base to 2 of altitude.

3rd. The part comprised between the lowest spring-tide and a horizontal plane 15 feet below it, is exposed to the shock of the waves only during the interval between the termination of the fall and the commencement of the rise of tide: it has, therefore, to withstand the efforts of the sea under a less inclination, viz., 3 feet base to 1 foot of altitude.

4th. The lowest part of the slope comprehended between the latter plane and the bottom of the sea, remaining permanently submerged, and to a depth at which the agitation of the waves has attained its minimum, has assumed an inclination still less than the preceding, viz., 5 feet base to 4 feet of altitude.

These experimental results show that the effect of water against loose materials is to give to the mass in progress of time a slope, the inclination of which will increase in proportion to the force exerted against it.

It is on these data that the profile of the Delaware Breakwater has been delineated. The Board was, however, aware that local circumstances and the bulk of materials might render a modification of this profile necessary; but it may be considered as the nearest possible approximation, sufficient to found upon it an estimate of the expense, and to direct in the construction of the work.

The preservation of the works above the highest spring-tide was a point upon which the Board had again to consult experience. At Cherbourg it was at first contemplated to keep the top of the breakwater a foot only above the highest spring-tide; but it was subsequently observed that extraordinary rises of sea caused by violent storms not only jeopardized the vessels moored in the roads, but threatened destruction to the upper portion of the work. It was, therefore, resolved to raise the top 9½ feet above the highest spring-tide. At Plymouth the top had been kept but 3 feet above the highest tide, but in January, 1817, a violent storm

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having raised the water 6 feet above the usual elevation, that part of the work which had been completed was swept at its top 200 yards in length and 90 feet in breadth; and all the blocks, weighing from 2 to 5 tons, were thrown on the inward slope. Such an extraordinary effect could not readily be ascribed to the pressure and velocity of a body of water however great, were it not for the fact that blocks of stone lose by immersion one-third of their weight.

This fact, with others not dissimilar which have happened at Cherbourg, shows that the top of a breakwater must be elevated beyond the reach of submersion, and loaded with the largest and heaviest materials that can be procured, which should be laid in such a way that each shall present to the action of the sea the smallest possible superficies, and to the lateral materials the largest surface of friction.

When it is considered that the Delaware Breakwater will not, like the works at Cherbourg and Plymouth, be exposed to any perpendicular shock; that towards the open sea it will be exposed only to waves raised by the east-north-east wind; that the greatest rise of water caused in Cape Henlopen roads by heavy storms, never, it is believed, exceeds $2\frac{1}{3}$ feet, —the Board was convinced that by keeping the top of the Delaware Breakwater $5\frac{1}{3}$ feet above the highest tide, there would be no danger of submersion. If, however, during the construction of the work, experience should afford more accurate data, the top might then be raised higher, if found necessary.

These considerations induced the Board to recommend for the Delaware Breakwater a profile, or transversal section, of the following dimensions:—the inward slope at 45°, the top 30 feet in breadth, and at $5\frac{1}{3}$ feet above the highest spring-tide; the outward slope of 39 feet altitude, and of $105\frac{3}{4}$ feet base; both dimensions measured in relation to a horizontal plane passing by a point taken at 27 feet below the lowest spring-tide. The base bears to the altitude nearly the same ratio as similar lines in the profiles of Plymouth and Cherbourg Breakwaters.

It remains now to make an estimate of the work, and

to submit some views in relation to the mode and progress of construction; but it is necessary previously to determine the various sizes of the materials best calculated to secure the permanent stability of the whole mass.

The experience acquired at Cherbourg has taught—

1st. That stones of small size are not sufficient to withstand even a moderate action of the waves; for, being constantly tossed about, they acquire by attrition a round and smooth surface, which prevents their assuming any settled place in the mass.

2nd. That stones measuring 18 to 24 cubic feet, and weighing $1\frac{1}{2}$ to 2 tons, present a suitable resistance to the efforts of a moderate sea.

3rd. That larger blocks are required to withstand a violent sea; and that in the more exposed parts of the work their size should be still larger.

4th. That if small materials were to be used, it would be indispensable to protect them externally by others of larger size.

5th. That the smaller the external surface of a large block, the greater will be its stability.

6th. That the largest blocks should be placed towards the top, in order to compensate, by their greater steadiness, the loss of weight and of stability caused by immersion to the materials located immediately under the water line.

At Cherbourg and at Plymouth the blocks used at the top measured each from 72 to 90 cubic feet, and weighed 5 to $6\frac{1}{2}$ tons.

The Board, in consideration of these facts, recommended the following arrangements and size of materials in the formation of the Delaware Breakwater, viz.: for the part comprehended between the sea bottom and a horizontal plane 6 feet below the lowest spring-tide, the mass to be formed of stones weighing from $\frac{1}{4}$ to 2 tons, those of 2 tons comprising three-fourths of the mass. The slopes of this part to be covered with blocks weighing from 2 to 3 tons.

For the part comprised between the latter horizontal plane

and the lowest spring-tide, the mass to be composed of stones weighing from ½ to 2½ tons; those of 1½ to 2½ tons forming three-fourths of the mass. The slope of this part to be protected by blocks weighing 3 tons.

For the part comprehended between the lowest and highest spring-tide, the mass to be formed of blocks weighing from 4 to 5 tons, and laid as regularly as practicable. The slopes of this part to be formed of the largest blocks, and to be laid headwise.

Respecting the precautions to be taken during the erection of the work, it must be borne in mind that the waves will act against the loose materials in two distinct ways.

1st. When striking the rock in a perpendicular direction, their effect will be to lift the materials, and force them up along the slope, where they will accumulate and assume a steeper inclination to the horizon.

2nd. When the waves are forced obliquely against the work, they sweep off the materials longitudinally along the slope, and cause an accumulation of materials inside of each end of the work, where they consolidate.

With the view of guarding against such effects, the Board recommended that the work should be commenced simultaneously, beginning at the western end of that portion designed particularly for a breakwater, and at the eastern end of that portion intended for an ice-breaker. Thus the latter end would shelter the former from the effect of winds from the north-west, and leave less danger to be apprehended from an accumulation of materials inside of the eastern extremity of the work. Besides, by such an arrangement a partial result would be annually obtained, and the work could progress according to the appropriations which Congress might think proper to make for the gradual execution of the whole plan.

It was also recommended, that in commencing the work the materials should be thrown inside of a line drawn parallel to the interior line of the top of the work, through a point at 22 yards distance. For it has been stated before, that the breadth of 30 feet may be safely deemed a maxi-

mum, and that a smaller breadth may be tested during the execution of the work; that of 22 feet will probably be found sufficient, especially for the ice-breaker.

It was deemed advisable, that as soon as the work should make its appearance above low-water mark, materials of weight should be heaped up at the head of the outward slope, with a view to prevent the stones lifted up along this slope from passing inside of the work.

The estimate submitted by the Board was as follows:— The profile of the work (exhibited in Plate XVII.) rests on a bottom of 29$\frac{4}{10}$ feet, on an average, below the lowest spring-tide, and has a superficies of 535,472 square yards; which, being multiplied by 1700 yards (the whole length of the work), gives for the capacity of the mass 910,302$\frac{4}{10}$ cubic yards.

The contract approved by the naval department to supply the Breakwater with stones weighing from $\frac{1}{4}$ of a ton to 3 tons and upwards, allowed $2·20 per perch, or 25 cubic feet. The cubic yard will therefore cost $2·376, which, multiplied by 910,302$\frac{4}{10}$, will produce the sum of $2,162,878·50, and by adding, for contingencies, 2$\frac{1}{2}$ per cent., $54,071·96, will make the whole cost of the work $2,216,950·46.

The price of stone included, agreeably to contract, its transportation to the Breakwater and its deposition in the water at the place designated.

With regard to the quantity of materials, no allowance was made in the estimate for the settling of the work, because the stones, which by contract were to be perched at the quarry, would, when thrown promiscuously into the water, occupy such additional space as to supply any deficiency from settling.

As to the defence of the harbour, a small casemated tower (estimated to cost about $15,000), mounting six guns, and protecting a temporary battery, was considered sufficient.

The foregoing description of the Delaware Breakwater includes, with occasional alterations, the Report

of the Board of Commissioners. The Work has been executed so far in accordance with the views and plans therein detailed. The dimensions recommended in the Report have been adopted in its erection, with the exception of that portion designed for a Breakwater, which is 1000 yards in length; the length recommended was 1200.

The Work may be considered now so far finished as to have accomplished materially the purposes for which it was projected. Indeed, the plan of commencing the Work at the adjacent extremities of its two portions has tended to yield a shelter to vessels during the whole progress of its construction. (See Plates XVII. and XVIII.)

WILLIAM STRICKLAND,
Architect and Engineer.

Philadelphia, Feb. 12, 1840.

PHILADELPHIA WATER WORKS.

THE following description and details of this valuable Work have been compiled from the Reports of the Watering Committee, made to Councils at various times. Plates XIX. to XXIV. exhibit the most important portions of it, and were copied from the original designs prepared by FREDERICK GRAFF, Esq., the Engineer and Superintendent of the Water Works, who promptly furnished every information required by the Editors respecting them.

DESCRIPTION.

This important Work, the property of the city of Philadelphia, was commenced by Ariel Cooley, with whom a contract was made for the erection of the dam, the locks and canal, the head arches to the race, and the excavation of the race from a solid rock, for the sum of 150,000 dollars. This work is a monument to his memory; and he had nearly completed it, when he was taken off by a disease, supposed to have been contracted by his exposure to the sun and night air, at the closing part of his work. His talents, his integrity, and his general worth, will long be held in grateful remembrance by the citizens of Philadelphia.

It will be proper, in this stage of the Report, to state the nature of the work that was to be accomplished, and to expose certain of its difficulties. The river is 900 feet in width, one-fourth of which, at the bottom, on the eastern side, is supposed to be rock, covered with about 11 feet of mud; the remainder is of rock. The greatest depth is 30 feet at high water; and it gradually shoals to the western shore, where the rock is left bare at low tide. The river,

whose average rise and fall is 6 feet, is subject to sudden and violent freshets.

Mr. Cooley determined, where rock was to be found, to sink cribs, formed of logs, 50 feet up and down stream, by 17 or 18 feet wide, which were sunk and filled with stone, and securely fastened to each other above low water, having the up-stream side planked from the bottom to the top; and the space immediately above filled to some extent with earth and small stones to prevent leakage. In that part where mud was found a mound is made with quarry spalls and earth, and raised about 15 feet higher than the dam; the base of this mound is 150 feet, and its width on the top 12 feet; and the whole of the top and of the up-stream side from the water edge is paved to the depth of 3 feet with building stone. Between the mound and the dam there is sunk on the rock, in 28 feet water, a stone pier, 28 feet by 23 feet, which supports the end of the mound, and protects it from injury by ice or water. The contraction of the river by the mound suggested to Mr. Cooley the idea of forming the dam in a diagonal line running up-stream, and when nearly over to run the rest of the distance at right angles towards the shore, so as to join the head pier of the guard-lock on the western side, by which means a large over-fall was created, and the rise above the dam, in case of freshet, considerably abated. The whole length of the over-fall is 1,204 feet; the mound 270 feet; the head arches 104 feet; making the whole extent of the dam, including the western pier, 1,600 feet, and backing the water up the river about six miles. The water power thus created is calculated to be equal to raise into the reservoir, by eight wheels and pumps, upwards of 10,000,000 gallons. The lowest estimate of the quantity of water afforded by the river in the dry season is 440,000,000 per 24 hours; and as it is calculated, allowing for leakage, waste, &c., that 40 gallons upon the wheel will raise one into the reservoir, the quantity raised would be 11,000,000 gallons per day.

On the west side of the river there is erected a pier

and guard-lock, whence there is a canal extending 569 feet to two locks[7] of 6 feet lift each; below these locks there is a canal into the river 420 feet long. The locks are built of cut stone; the upper canal is walled on the east side, and on the west it is rock. The outer front of the locks and canal is protected by a wall. On the east side of the river the whole of the bank was a solid rock, which it was necessary to excavate to the width of 140 feet, to form a race and site for the mill-houses running parallel with the river. The length of the mill-race is 419 feet, the greatest depth of the excavation is 60 feet, and the least 16 feet: the gunpowder used alone cost the contractor upwards of 12,000 dollars. At the upper part of this excavation were erected the head arches, three in number, which extend from the east end of the mound to the rock of the bank, thus forming a continuation of the dam.

On the west of the excavation are erected the mill-houses, forming the west side of the race, which is supported on the other side by the rock rising above it 70 or 80 feet perpendicularly. The south end, or wall of the race, is also of solid rock; and the mill-houses are founded on rock.

The race is about 90 feet in width, and is furnished with water through the head arches, which allow a passage of water of 68 feet in breadth and 6 feet in depth, to which the race is excavated below the over-fall of the dam, and of course room is allowed for a continual passage of 408 square feet of water. These arches are on the north of the race, and the mill-buildings being on the west, the water passes from the race to the wheels, which discharge the water into the river below the dam. The gate of the centre arch is upon the principle of a lock-gate, and admits the passage of boats, &c., into the race; at the south end of the mill-buildings there is a waste-gate, 8 feet wide, by which (the upper gates being shut) the water can be drawn off to the bottom of the race.

The mill-buildings are of stone, 238 feet long and 56 feet wide. The lower section is divided into twelve apartments, four of which are intended for eight double forcing-pumps.

[7] These locks have since been doubled.

The other apartments are for the forebays leading to the water-wheels. The pump and forebay chambers are arched with brick, and are perfectly secure from the inclemency of the winter. Those now in use are kept warm by means of large iron stoves, heated to great advantage and economy with coal. A gallery is erected, extending the whole length of the building, from which all the wheels may be seen at one view. The centre part of the buildings is 190 feet by 25 feet, with circular doors to the pump chambers, and a range of circular windows over the archways of the wheel-rooms; on a line with the cornice of the central part is the base course of two pavilions, with Doric porticoes, which terminate the west front. One of these is used for the office of the Watering Committee, and the other is the residence of the person who has the general charge of the property at Fair Mount. On the east front, immediately over the pumps and forebay rooms, is a terrace, 253 feet long and 26 feet wide, paved with brick, and railed, forming a handsome walk along the race, and leading, by steps at the end, to the top of the head arches, mound-dam, and pier. In the erection of the mill-buildings, Mr. John Moore was employed as the mason; and to his care and skill we are much indebted, not only for the excellence of the work in appearance, but for its substantial properties, it being ascertained that in the whole extent of the foundation along the race, under a six feet head of water, there is no leak. Mr. Frederick Erdman, the carpenter, also deserves particular notice for his part of the work, which has been most faithfully done.

It has been from the commencement determined, for the present, to erect only three wheels and pumps, which are now completed,[8] and with them the most important part of the duty of the Committee. The first of the wheels is 15 feet in diameter and 15 feet long, working under 1 foot head and 7 feet fall. This was put in operation on the 1st of July, 1822, and it raises 1¼ million gallons of water to the reservoir in twenty-four hours, with a stroke of the pump of 4½ feet, a diameter of 16 inches, and the wheel making 11½

[8] There are now six.

revolutions in a minute. The second wheel was put in operation on the 14th of September, 1822, and is the same length as the first, and 16 feet diameter; it works under 1 foot head and 7½ feet fall, making 13 revolutions in a minute, with a 4½ feet stroke of the pump, and raising 1⅛ million gallons in twenty-four hours. The third wheel, which went into operation on the 24th of December, 1822, is of the same size as the second, and works under the same head and fall, making 13 revolutions in a minute, with a 5 feet stroke of the pump, and raising 1½ million gallons in twenty-four hours. It is not doubted that the second wheel can be made to raise an equal quantity; thus making the whole supply upwards of 4,000,000 gallons in twenty-four hours.

The wheels are formed of wood, and put together with great strength. The shafts are of iron, weighing about 5 tons each. The great size and weight of the wheel give it a momentum which adds greatly to the regularity of its motion, so necessary to preserve the pumps from injury under so heavy a head as they are required to work, which is a weight of 7900 lbs.; the height 92 feet.

The wheels being sunk below the usual line of high water, it might be supposed that they would be obliged to stop at that time; but this seldom happens, except in the spring-tides, at the full and change of the moon, which, upon the average, stops them about sixty-four hours in a month. It is found that they are very little affected until the back-water is about 16 inches on the wheel. The excellence of the work in the wheels and gates, with the whole arrangement of the mill-works, does the highest credit to Mr. Drury Bromley, whose attention has been most assiduous, and whose skill is of the first class.

The pumps were made by Messrs. Rush and Muhlenberg, according to the designs of Mr. F. Graff, Engineer, and are worked by a crank on the water-wheel, attached to a pitman, connected with the piston at the end of the slides. They are fed under a natural head of water, from the forebays of the water-wheel, and are calculated for a 6 feet stroke; but

hitherto it has been found more profitable to work with not more than 5 feet. They are double forcing-pumps, and are connected each of them to an iron main 16 inches in diameter, which is carried along the bottom of the race to the rock at the foot of Fair Mount, and thence up the bank into the reservoir. At the end of the pipe there is a stop-cock, which is closed when needful for any purpose. The shortest of these mains is 284 feet long; the other two are somewhat longer. The water being raised into the reservoirs, 102 feet above low tide, and 56 feet above the highest ground in the city, is thence conveyed to the city in iron pipes.

The satisfactory test to which the dam was exposed on the 21st of February, 1822, by an ice-freshet, which rose 9 feet above the over-fall of the dam, and which is supposed to be the greatest that has ever been known in the Schuylkill, has quieted all fears as to its safety, and done away all the objections that ever could be raised to resort to water power, where nature had kindly done so much.

The cost of the whole work done since the ordinance passed, April 18th, 1819, viz.

Purchase of White and Gillingham . . .	$150,000
Erection of the dam, locks, head arches, race, and piers, including estimate of damages for overflowing by the dam	181,000
Three pumps	11,000
Mill-houses, mills, and other work connected with them	71,250
Iron raising mains	4,480
New reservoir	8,600
Amounting together to . .	$426,330

The cost of iron pipes, it may be satisfactory to mention, is as follows:

22-inch pipes, per foot . . .			$6	25
20	do.	do. . . .	5	00
16	do.	do. . . .	3	33⅓

10-inch pipes, per foot	.	.	.	$2 40
8 do. do.	.	.	.	1 66⅔
6 do. do.	.	.	.	1 10
4 do. do.	.	.	.	0 64
3 do. do.	.	.	.	0 45
1½ do. do.	.	.	.	0 40

These prices do not contain the prices of lead, laying, &c., as the difference of situation makes so material an alteration. The 20-inch and 22-inch mains cost 7 dollars and 42 cents per foot on the average, but this includes the filling up of Hunter-street, &c.

The greater part of the pipes now laid, or on hand, were made in the United States, and the Committee have never imported any when they were to be had here, except as samples for the benefit of our manufacturers.

The Committee cannot close this Report without presenting, in the most distinct manner, to the notice of both the Councils and the city, Mr. Frederick Graff, for many years Superintendent of the Water Works, whose taste in the design, and whose judgment in the arrangement, of the works at Fair Mount, with his indefatigable zeal for the public interest in every department, have attracted the regard and thanks of the Committee, and entitle him to those of the Councils.

All which is respectfully submitted,
By order of the Committee,
JOSEPH S. LEWIS,
Chairman.

January 6th, 1823.

Extract from the Annual Report of the Watering Committee, dated January 3rd, 1824, to the Select and Common Councils of the City of Philadelphia.

The experience of another year has furnished results that will probably be interesting to Councils; and the Committee therefore trespass a little in detailing the beneficial results produced by the new Water Works at Fair Mount, which have exceeded the warmest anticipations of their most san-

guine friends. The calculations formed were of the most cautious kind, for there was little experience to guide in the construction of water works calculated to raise water, and hence it was stated that 40 gallons upon the wheel would be required to raise one to the reservoir; but experience has shown that 30 are more than ample, thus at once increasing the calculation of the water power of the river one-third. The quantity raised was also underrated at 1,000,000 gallons in twenty-four hours for each wheel and pump: it may now be safely stated at 1,250,000, supposing the wheel to work during the whole time; but this is not always the case, as the tide occasionally makes it prudent to stop them, to prevent straining the works.

An experiment was made in July last for eighteen days, during which time four fire-plugs were constantly in use during the day-time in washing the gutters, when two wheels and pumps were found adequate to supply the demand, and working only fourteen hours in twenty-four, and the consumption of water was 1,616,160 gallons in the same period of twenty-four hours. In October last the three wheels were found sufficient to supply the city in eight hours, equal to one wheel for twenty-four hours, and supplying 1,250,000 gallons. In the last month the wheels were stopped three days on account of the water being disturbed by a freshet, during which time the reservoir fell 52 inches. After the water had settled the three wheels were put in operation, and, besides supplying the city with about 1,250,000 gallons, they filled the reservoir in twenty-four hours, equal in all to 3,750,000 gallons. The demand of the city for water in very cold weather may be stated at about 1,000,000 gallons.

The advantage of large reservoirs is particularly observable during a freshet in the river, as the city can be supplied for several days with clear water from them whilst the muddy water is running off, during which time the wheels are of course stopped.

Two men are found sufficient to attend the works twelve hours at a time alternately night and day; and the calculation made last year of four dollars per day for wages, fuel, light,

tallow, &c., is, upon experience, found to be ample. The plan of warming the house has completely answered the object proposed, and no ice has formed in the coldest weather on the wheels or in the pumps.

The whole cost of the new works, including the damages, the new reservoir, and the preparation for a third one, is 432,512 dollars.

Extract from the Report of the Watering Committee, January, 1837.

The Watering Committee, in submitting their annual Report on the great public work committed to their care, deem it proper to present to the Councils a more extended notice of the Fair Mount Water Works than has been given since the year 1823, when the completion of what may be termed the experimental part of the water works was presented by our much respected fellow-citizen, the late Joseph S. Lewis, Esq., in the Report of the Committee for that year.

In the year 1799 the attention of the citizens of Philadelphia was first directed to the subject of obtaining for domestic purposes a copious supply of pure and wholesome water; and at the same time that so indispensable a necessary of life was obtained, to secure an ample quantity of the same element for the protection of the dwellings and property of the inhabitants from conflagration. Recourse was had to steam power to carry the views of the first projectors into effect; and, after two sets of works had been erected and crowned with success, which for the then limited population was deemed satisfactory, the forecast of the Councils who at that time administered the affairs of the city seized on the favourable circumstances of the improvement of the navigation of the river Schuylkill, to lay the foundation of the splendid works which are now the pride and ornament of Philadelphia. Acquiring, under the several contracts with the Schuylkill Navigation Company, the whole of the water and water power of the river Schuylkill at Fair Mount which might remain after sup-

plying the locks and canal constructed by the city to complete the navigation at that point, the Corporation has continued from year to year to make the most liberal appropriations for the completion of the works; and we now behold them with a capacity to supply the wants of a population twice as numerous as that now embraced within the limits of the city and adjoining districts. During the past year the two remaining sections of Reservoir No. 4 have been finished; and the Committee have the pleasure to state, that although the reservoirs are elevated 102 feet above the level of the tide in the river Schuylkill, with portions of them resting on upwards of 90,000 yards of artificial embankment, they have great solidity, and are all in good order. With the exception of some slight filtration through the rocky substratum of the reservoir last constructed they are water-tight, and the Committee have no doubt that when the materials of which that is built have consolidated it will also become perfect. The water rents payable from the city and districts for the year 1837 amount to $106,432·37, and are thus distributed:

City of Philadelphia	$57,080 50
Ditto, for the Girard Estate, and rents charged to H. J. Williams, for factories, &c. near Fair Mount	1,048 50
District of Spring Garden	13,674 25
District of the Northern Liberties . . .	20,009 37
District of Southwark	10,517 50
District of Moyamensing	1,956 00
District of Kensington	2,146 25
	$106,432 37

The water works at Fair Mount, as at present in operation, consist of a dam upwards of 1,200 feet in length, of a peculiar construction, and the race and mill-buildings minutely described in the Report of 1823; six water wheels, and as many double forcing-pumps, varying in a slight degree in the diameter of the wheels, and in the length of the stroke of the pumps, but conforming in their structure and appearance

to the original plan; and four reservoirs, divided into convenient sections, covering a superficial area of upwards of six acres. The average quantity of water raised by each wheel and pump daily for the past year was about 530,000 gallons, which is elevated into the reservoirs 102 feet above the level of the tide in the Schuylkill, and distributed from thence through 98¾ miles of iron pipes, which can be separately controlled by a very simple apparatus. The reservoirs are built of stone, and paved with bricks laid upon a very tenacious clay puddle in strong lime cement, and covered with grouting to prevent leakage. They are surrounded by an artificial embankment 38 feet high, the base line of which is about 40 feet, composed of strong clay immediately in contact with the walls of the reservoirs, and forming a belt about 2 feet thick, and the remaining portion of good loam, the whole being neatly faced with grass sods, which prevent washing. The reservoirs are each 12¼ feet deep, and will contain, when filled, upwards of 22,000,000 gallons of water. The pumping apparatus now in use will furnish a supply of 6,000,000 gallons per day, and that quantity may be increased to 8,000,000 gallons daily by the erection of two more wheels and pumps, which will complete the original design and fill up the mill-buildings. The whole cost of these works to the 1st instant amounts to £1,381,031·43, which includes all the pipes and fixtures of the old steam power works applicable to the distribution of water on the present plan.

The following statement exhibits the extent of the works, the number of tenants supplied, the quantity of water daily distributed, and the amount of revenue for the years 1823 (at which time the city only was supplied with water) and 1837 respectively. In 1823 the three wheels and pumps were in operation, 6½ miles of iron pipes were laid, 4,844 tenants were supplied with 1,616,160 gallons of water daily, and the revenue was £26,191·05 per annum. In 1837 six wheels and pumps are in operation, 98¾ miles of iron pipes are laid, 19,678 tenants are supplied with 3,122,164 gallons of water daily, and the revenue is £106,432·37.

In conclusion, while the Committee congratulate the Councils on the present condition and prospects of Fair Mount Water Works, they cannot omit paying a public tribute of respect to Frederick Graff, Esq., who for nearly thirty-two years, in the arduous and responsible duties of Engineer and Superintendent of the works, has most signally contributed to their success, and won for himself an enduring name and the lasting gratitude of his fellow-citizens.

JOHN PRICE WETHERILL,
Chairman of the Watering Committee.

Philadelphia, Jan. 5, 1837.

Particulars relating to the Fair Mount Water Power Works, from their commencement up to December 31*st*, 1836.

The dam was commenced April 19, 1819, and finished July 23, 1821.

The great ice-freshet, which rose 9 feet above the dam, took place February 21, 1822.

The corner stone of the mill-buildings was laid April 28, 1821.

The wheel and pump No. 1 was first put into operation			July 1, 1822
No. 2	do.	do.	Sept. 14, 1822
No. 3	do.	do.	Dec. 24, 1822
No. 4	do.	do.	Nov. 10, 1827
No. 5	do.	do.	April 5, 1832
No. 6	do.	do.	Nov. 5, 1834

The 22-inch iron main was laid in 1820.
The 20-inch iron main was laid in 1829.
Each of these is nearly 10,000 feet in length.

	Gallons.	Gallons.
The reservoir No. 1 was finished in 1815; containing	3,917,659	
The reservoir No. 2 was finished in 1821; containing	3,296,434	
Carried forward . . .		7,214,093

	Gallons.	Gallons.
Brought forward		7,214,093
The reservoir No. 3 was finished in 1827; containing	2,707,295	
The first section of reservoir No. 4 was finished in 1835; containing . .	3,658,016	
The second section of reservoir No. 4 was finished in 1836; containing . .	4,381,322	
The third section of reservoir No. 4 was finished in 1836; containing . .	4,071,250	
		14,817,883
The reservoirs contain together		22,031,976

Reservoir No. 1 cost	$32,508 52
Reservoir No. 2 cost	9,579 47
Reservoir No. 3 cost	24,521 75
First, second, and third sections of reservoir No. 4 cost	67,214 68
	$133,824 42

The waters of the reservoirs cover a surface exceeding six acres. The reservoirs are each 12 feet 3 inches deep, and are elevated above the water in the dam 96 feet perpendicular.

The water flowing from the reservoirs for the supply of the city and districts, per day, at different periods of the year 1836, was as follows:

		Gallons.
(In very cold weather), from	Feb. 1 to 21 . .	1,769,800
	Feb. 21 to March 20 .	2,113,257
	March 20 to June 3 .	3,046,120
	June 3 to July 22 .	3,942,643
	July 22 to Sept. 9 .	4,152,917
	Sept. 9 to Oct. 28 .	3,679,800
	Oct. 28 to Dec. 31 .	3,154,114

The average daily supply in 1836 was 3,122,664 gallons.

The above supply of water is distributed to 10,632 tenants

by private hydrants, and to 3,000 families by hydrant pumps.

			Tenants.
In the city to			13,632
And by private hydrants in the district of		Spring Garden to	1,762
Do.	do.	Southwark to	1,287
Do.	do.	Northern Liberties to	2,535
Do.	do.	Moyamensing to	228
Do.	do.	Kensington to	234
		Together	19,678

Being an average daily supply to each tenant of 160 gallons.

The quantity of iron pipes laid for the distribution of the water is as follows:

	Miles.
In the city	58
In Spring Garden	11⅛
In Southwark	10¼
In the Northern Liberties	12⅞
In Moyamensing	2⅝
In Kensington	3⅜
Together	98¾

The water rents up to the 31st of December, 1837, were as follow:

For the city	$57,080	50
Including rents on the Girard Estate, and rents due by H. J. Williams and others at Fair Mount	1,048	50
For Spring Garden	13,674	25
For Southwark	10,517	50
For the Northern Liberties	20,009	37
For Moyamensing	1,956	00
For Kensington	2,146	25
Together	$106,432	37

The expenses for the Water Power Works, connected with the applicable parts of the former steam works, were, December 31, 1831 . .	$1,138,323	54
Add the expenses for reservoirs, iron pipes, &c. in 1832	65,195	58
Do. do. in 1833 .	37,354	06
Do. do. in 1834 .	65,163	36
Do. do. in 1835 .	73,288	38
Do. do. in 1836 .	71,706	51
	$1,451,031	43
From which deduct, for the support of working machinery, materials, salaries, &c. $14,000 per annum for the last 5 years	70,000	00
Leaving the expenditure for the permanent works, up to the 31st December, 1836 . . .	$1,381,031	43

The contract for supplying the district of Spring Garden with water was signed April 26, 1826.

The second contract for the extension of the water from Broad-street to the Schuylkill, October 10, 1831.

Agreement with Southwark signed June 1, 1826.

Agreement with the Northern Liberties signed June 6, 1826.

Agreement with Moyamensing signed January 6, 1832.

Agreement with Kensington signed October 5, 1833.

FREDERICK GRAFF,
Engineer and Superintendent of
Fair Mount Water Works.

Particulars relating to the Fair Mount Water Works.

There are six wheels and pumps now placed at Fair Mount, which are capable of raising 61,330 gallons per hour, or per twenty-four hours, 8,831,520 gallons.

The daily consumption of water used in the city and districts, during the year 1837, was as follows:

	Gallons.
From January 6 to March 31, a term of 12 weeks, the supply was per day	2,418,154
From March 31 to June 23 do. do.	3,469,525
From June 23 to Sept. 15 do. do.	4,205,485
From Sept. 15 to Dec. 18 do. do.	3,732,368

The average daily supply for the year 1837 was 3,456,383 gallons.

	Tenants.
The above supply of water was distributed to 10,977 tenants by private hydrants, and to 3,000 families by means of public hydrant pumps placed in the city, together equal to	13,977
And by private hydrants in the district of Spring Garden	1,925
Do. do. Southwark	1,366
Do. do. Northern Liberties	2,621
Do. do. Moyamensing	295
Do. do. Kensington	278
Together	20,462

Being an average daily supply to each tenant of 168 gallons.

Statement of iron pipes laid in the city and districts, commencing October, 1819, to December, 1838.

	Feet.
City of Philadelphia	326,128
Spring Garden	72,604
Northern Liberties	69,961
Southwark	55,616
Moyamensing	14,872
Kensington	23,969
	563,150

Equal nearly to 106⅔ miles.

The daily consumption of water used in the city and districts during the year 1838 was as follows:

	Gallons.
From January 1 to April 1 the average daily supply of water was	2,628,428
From April 1 to July 1	3,942,642
From July 1 to Oct. 1	5,151,720
From Oct. 1 to Dec. 31	3,679,800

Being an average for the year of 3,850,647 gallons.

The water rents up to the 31st December, 1838, were as follow:

For the city	£60,081 25
For Spring Garden . . .	15,046 50
For Northern Liberties . .	20,651 37
For Southwark . . .	11,236 25
For Moyamensing . . .	2,373 00
For Kensington . . .	2,503 00
	£111,891 37

The expenses for the erection of the Water Works, and for iron pipes, &c. up to Dec. 31, 1836, were	£1,381,031 43
Add for the extension of the iron pipes, for the completion of the reservoirs, and other permanent improvements, to December 31, 1837 .	35,730 10
Making the expenditure for the permanent work	£1,416,761 53

DAM NO. I. ON THE EASTERN DIVISION OF THE SANDY AND BEAVER CANAL, OHIO.

THIS Work (see Plates XXV. to XXX.) was designed by E. H. GILL, Chief Engineer of the Sandy and Beaver Canal Company.

The following is a copy of the Specification:

The manner of constructing the dam will be as follows:—Six spaces shall be excavated across the stream to the depth required by the engineer, or at least two feet below its bed; in those spaces foundation timbers, 10 inches square, are to be laid; on these timbers the sheeting timbers of the dam are to be placed, and firmly pinned to them with locust pins, 2 inches in diameter and 22 inches long; six pins to each sheeting timber. The foundation timbers are to let into the sheeting timbers 2 inches, the sheeting timbers are to be 10 inches square, and to extend 12 feet below the breast of the dam, and are to be laid at right angles to the foundation timbers close together, every fifth stick to be the full length upstream of the dam; the remainder to be 14 feet in length and to extend from abutment to abutment. The dam is to have a base of 3 feet to every foot in height, exclusive of the 12 feet below the breast for sheeting.

After the sheeting has been laid and bolted, two rows of timber, 12 inches square, one at the head of the dam and the other 12 feet above the lower end of the sheeting, are to be laid on the sheeting timbers, at right angles thereto, and the entire space between them to be covered with 2-inch plank. These timbers shall be let into the sheeting timbers 2 inches, and connected together by white oak ties, 10 inches square, dovetailed accurately and tightly fitted into tenons made in the timbers to receive them. The ties are to be placed 10 feet

apart on each course of timber; the back and front logs are to be placed over and to rest on each other for the first 4 feet in height of the dam, the front logs to be carried up perpendicular, the back logs to batter 3 inches for each foot in height. Wherever a tie connects with a timber, it must be fastened with a locust pin, 2 inches in diameter and 30 inches long; these ties must be inserted in every course of timbers at each 10 feet in length of the dam.

The whole is then to be carried up by means of back, front, and intermediate logs, as shown on the Plan, till it is raised within 19 inches of the contemplated height, being filled, as it progresses, with stone closely packed.

After the dam has been raised, as above mentioned, within 19 inches of its height, the last course of ties being 4 feet apart, eight courses of 10 by 10-inch timbers are to be laid across the dam at equal distances apart, at right angles to the ties, and resting on the last course, and firmly bolted to them. The whole upper and lower or face surface of the dam must be covered with 3-inch white oak plank, well and tightly fitted; the plank to rest on the timbers last above described, and on the ends of the ties and front logs, and to be secured to them by wrought-iron spikes, 8 inches long. On the upper plank must be secured ice-guards, 6 inches thick at the butt and tapering to an edge, each guard-plank to be 10 feet long, and to be fastened with 14-inch wrought-iron spikes, five spikes to each plank.

The upper and lower ends of the dam are to be well sheet-piled with 2-inch white oak or pine plank battened; there is also to be a row of sheet-piling under the breast of the dam, the sheet-piles not to be less than 4 feet long.

All the timber used in the construction of the dam must be perfectly sound, free from rot or sap, and no other timber than white oak, chestnut, oak, pine, or hemlock will be permitted to be used. The plank must be of the best quality of white oak, perfectly sound.

There is to be a sluice in the dam, of such width and description as the engineer may require. The up-stream side of the dam is to be well gravelled; the abutments are to be

built of large cut stone, coursed and laid in hydraulic cement, and coped with stones 3 feet wide and 12 inches thick, cut and laid in a workmanlike manner. The abutments are to be sheet-piled on the back, and wherever the engineer may require.

Bill of Timber, Plank, Iron, and Stone Filling, for 100 *feet in length, of Dam No. I.,* 15 *feet high.*

4500 linear feet of mud sills and range timber, 10 by 10 inches square, not less than 30 feet long.
120 sticks, 10 by 10 inches square, 20 feet long.
20 sheeting-sticks, 10 by 10 inches square, 60 feet long.
105 ties, 10 by 10 inches square, 40 feet long.
10 supports, 10 by 10 inches square, 9 feet long.
3700 feet 3-inch plank, and 100 ice-guards, 10 feet long.
7800 feet 2-inch plank.
2000 feet boards.
1000 pounds of 8-inch bolts, $\frac{1}{2}$ inch square.
600 pounds of 14-inch bolts, $\frac{3}{4}$ of an inch square.
200 pounds of spikes, 6 inches long.
1600 cubic yards of stone filling.
Sum total of timber, 12,390 linear feet.

SPECIFICATION FOR A LOCK, SANDY AND BEAVER CANAL.

E. H. GILL, CHIEF ENGINEER.

Locks—Dimensions.—Locks shall be 90 feet long in the chamber between the upper and lower gates, and 15 feet broad in the clear. The foundation shall be laid at such level or elevation as the engineer may prescribe, but in all cases so low that the top of the lower mitre sill will be 4 feet below the top water line of the canal below the lock. When a good even foundation of solid, compact, and durable rock cannot, in the opinion of the engineer having charge of the work, be procured at the proper elevation, the foundation shall be composed of good, sound, hard, and durable timber, hewed square, and not less than 10 inches in thick-

ness, which shall be laid horizontally crosswise of the lock-pit, level and even, not less than 3 nor more than 5 inches beyond the outward base of the walls. This timber shall rest on a bed of good gravel puddle of such depth as the engineer may deem necessary and shall direct, into which it shall be driven or sunk at least one inch, and the spaces between the timbers shall also be perfectly filled with good puddle, composed of gravel and such other suitable materials as said engineer may designate, which shall be thoroughly rammed and packed, beginning at the bottom of each space. Four rows of sheet-piling, to be composed of good, sound, straight, and square-edged white oak plank, set close together, spiked and battened, extending to such depths as said engineer may deem necessary, shall be set in the ground across the foundation, in a ditch to be cut for that purpose, which shall be thoroughly filled with good puddle, well rammed.

A floor to be composed of good sound 2-inch pine, or white oak plank free from shakes, well jointed, so far as to form tight joints both at the sides and ends, shall be laid over the whole foundation of timber above described, and thoroughly trenailed and spiked down to the timber underneath with 6-inch spikes. Over this floor and between the lock walls a second floor of good sound 2-inch pine or white oak plank, well jointed and water-tight, is to be laid, and firmly spiked to the first with 6-inch spikes.

The thickness of the lock walls, and all other matters relating to the locks not herein specified, to correspond with the plans and directions of the engineer.

The face of the lock walls shall be laid in courses, or range work, composed of cut stone; the stone forming each course to be of equal thickness through the whole course. No face stone shall be less than 1 foot in thickness, unless the engineer shall admit of stone of less thickness to be used. Every face stone shall be at least 14 inches in breadth throughout its whole length, and in no instance shall be of less breadth than thickness. No face stone shall be more than half an inch thicker at the face than at the

back, and shall be as nearly of uniform thickness throughout as may be. The joints or edges of face stone shall be straight and square both on the beds and at the ends, and the corners full, making close joints at the ends from the face back 12 inches at least. Headers not less than 2 feet broad and 4 feet 6 inches in length, and as large throughout the whole length as at the face, shall be prepared and laid into each course, except the bottom and top courses of the face wall, not more than 10 feet apart, measuring from centre to centre, in any place, and so arranged that the headers in each successive course will be placed over the space between headers in the course beneath.

The face stone of the locks shall be laid in good, well wrought mortar, free from pebbles and lumps of raw lime. The mortar shall be composed of proper proportions of good water-proof lime and clean sharp sand, the proportions of each to be determined by the engineer. The stone shall be laid with close joints, not exceeding in any case $\frac{3}{16}$ths of an inch in thickness; and both the horizontal and perpendicular joints shall be thoroughly and completely filled with mortar, extending from the face of the wall at least 12 inches back. The face stone shall be thoroughly wet before being laid, and the walls shall be kept constantly wet during the time of their being built, and the face stone shall break joints in all cases at least 12 inches. The coping stone shall be at least 3 feet in breadth, of uniform thickness at the face and on the back, and shall be cramped together with iron cramps of the proper form and size. The head of the lock on each side shall be defended by placing a heavy stone of at least 2 feet in thickness, $2\frac{1}{2}$ in breadth, and 5 feet in length, in the upper course extending from the gate recess at the head; the joints to be all pointed with Roman cement.

Backing.—All parts of the lock walls not occupied by the face stones shall be composed of good large solid stone, well shaped, so as to form a strong bond throughout the whole, none of which shall measure less than 5 cubic feet; all the

stones are to be hammer-dressed, so as to have good square joints and level beds, and to be laid close; all the backing stones to have the same thickness that the face stones in front of them have. Headers not less than 12 inches in thickness and 24 inches in breadth throughout their whole length, and extending from the back into the wall 4 feet (or at least so far as the face stone will permit them to extend), shall be so placed as to correspond with each course of the face wall, and so that one header from the back side shall extend into each space between the headers of the face; the back and face headers interlocking with each other so as to bind the whole wall firmly together. The wall shall be grouted throughout its whole extent, after laying each course of face stone and raising the back wall even therewith from time to time as the wall advances in height, and more frequently if the engineer having charge of the work shall direct.

All stone used in building locks shall be solid, firm, and durable, not liable to be affected by the action of water and frost; especial care must be taken to see that all face stones are of this character. No stone is to be cut, dressed, or hammered on the wall; the walls are at all times to be kept perfectly clean and free from sand or dust by means of brooms, and are not to be embanked for at least one month after their completion.

The lock gates and mitre sills shall be made agreeably to plans to be furnished by the engineer having charge of the work, and shall be composed of good, sound, solid white oak timber and plank, and thoroughly secured with iron of good quality and proper dimensions, made and formed agreeably to bills and plans to be furnished by said engineer.

Fender beams and posts of proper size and dimensions, of good sound white oak timber, shall be placed and secured at the head and foot of the locks agreeably to a plan to be furnished, and the directions which shall be given by the engineer having charge of the work.

The bottom and sides of the canal, extending from the foot of the lock at least 40 feet, shall be secured from the action of the water passing through the valves by being

paved with rough stone, as may be directed by the superintending engineer. A tumble to be built, agreeably to a plan to be furnished, of cut or hammer-dressed stone, if required by the engineer, to pass the water from the level above to that below the lock.

SPECIFICATION FOR THE JOSHUA'S FALLS DAM, JAMES RIVER AND KANAWHA CANAL, VIRGINIA.

CHARLES ELLET, JUN., CHIEF ENGINEER.

(Plates XXXI. and XXXII.)

Dimensions.—1st. The dam shall be about 580 feet long between the faces of the abutments. Its height above low water in the river shall be about 10½ feet, and above the bottom of the river from 11 to 18 feet; the width at the base shall be 28½ feet.

2nd. The foundation shall be formed of 12-inch square timbers, 29½ feet long, placed parallel, up and down stream, 5 feet apart from centre to centre, fitted as closely as practicable to the rock in the bottom of the river. The ends of these timbers shall be sawed off square, and the upper ends shall be ranged parallel with the line of the dam. These timbers are represented on the Plan by the letter A. Their upper sides will be notched, at the position of the timbers B, B′, B″, B‴, in places where the water is 2½ feet deep, 3 inches deep.

3rd. The timbers B, B′, B″, B‴ shall be let into these notches and secured by locust trenails, 20 inches long and 2½ inches diameter, to the timbers A. The up-stream side of the timber B shall come flush with the upper ends of the timbers A. The timbers B, B′, B″, B‴ shall likewise be notched 3 inches on their upper sides, in order to receive the timbers C. The notches in the timbers B and B‴ shall be of a dovetail form, and the ends of the timbers C shall be cut in the same shape, and accurately fitted to them. Trenails similar to those formerly mentioned shall secure the timbers C to the timbers B and B‴.

4th. The timbers C shall be the tie-beams of the frame of the dam, which shall consist of a series of trusses, formed of a vertical post D, and two principal rafters, E and F, and the braces G, G′, G″. In framing the dam the rafter E shall be mortised into the rafter F, the end of the latter projecting 5 inches beyond the down-stream side of the former.

The post D shall be mortised into the rafter F and into the tie C, and shall be secured at the ends by $1\frac{3}{4}$-inch oak or locust pins. The tenons of the braces and of the principal rafters shall be secured in like manner.

5th. The rafter F shall be covered with five ribs, of which the upper one, H, shall come flush with the ends of the rafters F, and the lower one, H″, flush with the ends of the timbers C. Both H and H″ shall be cut out of 12-inch square timber, placed with their upper surfaces parallel with the slope of the dam. The upper corner of the timber H shall be hewed or sawed off to the slope of the planking on the lower side of the dam, and the corner of the timber H″ shall be hewed down so as to present a vertical face on the upper side, which face shall be laid flush with the ends of the timbers C, and the side of the timber B.

The rib H, and the upper rib H′, shall be bolted to the rafter F by $1\frac{1}{4}$-inch iron bolts, furnished with a head on the lower end, and a screw to receive a burr bearing against a shield on the upper end. The rib H″ shall be trenailed to the timber C. The two intermediate ribs H′ shall be 10 by 12 inches, and shall be notched 6 inches, and laid upon the principal rafters, to which they shall be secured by trenails, and, together with all the other ribs, with sufficient wedges.

6th. There shall be four ribs, of which the three upper shall be 10 inches square on the rafter E. The upper side of the upper rib L shall be hewn off so as to permit it to fit closely to the under side of the rafter F, and it shall be secured to the rafter E by an iron bolt and burr, as described for the rib H. These ribs shall be notched 5 inches, and the lower rib L″ shall be notched so as to fit both the rafter E and the tie C. The rib L″ shall be 10 by 12 inches, and

the ribs L′ and L″ shall be secured by trenails. Wedges shall be tightly driven between all the ribs and the rafters upon which they rest, so as thoroughly to secure the trusses from any lateral motion.

7th. There shall be a course of 3-inch sheet piling on the upper side of the dam, which shall be as closely fitted to the rock as it is practicable to fit it. The upper ends of the pile plank shall be sawed off level with the top of the rib H″, and spiked or trenailed to the upper side of it.

8th. After the framing is raised, and before the upper ribs are laid, the whole of the interior of the dam shall be filled, partly by stone thrown in promiscuously, and partly by walling.

From the lower face of the post D, to a point 5 feet above it at the bottom, and 4 feet at the top of the post, shall be laid a regular vertical wall. This wall shall be started, if practicable, from the rock in the bottom of the river, and shall be raised of large and well shaped stones up to the level of the under side of the planking. The lower face of the wall shall be flush with the lower faces of the posts D. The batter on the back of the wall shall be perfectly uniform from top to bottom. Both faces of the wall shall be well finished, and the stones shall be laid so as to produce a substantial bond throughout. The space above this wall shall be filled with large and small stones thrown in promiscuously, care being taken to fill up the spaces between the timbers A and C with stone closely wedged in them.

The space under the timber B‴, and between the timbers A, shall be filled up compactly with the largest stone that can be forced into it from the upper side; and the whole space below the wall from the bottom of the river up to the top of the timber C, except a space of 3 feet immediately back of the timber B‴, shall be filled with very large stone. The spaces between these large stones shall be filled in carefully, if required by the engineer, with smaller stones and spalls.

9th. Back of the timber B‴ shall be raised a vertical wall, 3 feet wide, up to the top of the timber C. This vertical

wall shall serve as the foundation of a slope wall, which shall be built along the whole face of the dam, flush with the lower faces of the ribs L, &c., having a width at bottom of $2\frac{1}{2}$, and at top of 2 feet. This slope wall shall rest upon the vertical wall back of the timber B‴. It shall be built with extreme care, and consist, as much as practicable, of headers and stretchers, the headers generally running entirely through the wall. Wherever the wall comes in contact with the ribs L, L′, &c., or the rafters E, the stone shall be wedged firmly around them; and, in short, the whole wall shall be so laid that no stone can be worked out by the hand from the lower side.

10th. Before the ribs L″ are secured there shall be short timbers, P, fitted into all the spaces between the ties C, and under the ribs L″. These timbers shall be hewn so as just to fill the spaces left vacant there, and shall each be secured to the timbers B‴ by three trenails of the description given above.

11th. There shall be a course of 4-inch planking, K, placed on the lower side of the dam. This planking shall be sawed off even with the upper surface of the rib H, so as to receive the plank M, which shall be 3 inches thick directly over it.

Over the plank M there shall be another course of 3-inch plank running 4 feet back from the crest of the dam, and projecting 2 inches beyond the course on which it rests.

All the plank on the lower side of the dam shall be of the precise length of the slope which it is to cover. Splicing will not be permitted.

Of the planking on the upper side every piece which comes up to the top of the dam shall bear on at least three of the ribs, and shall, consequently, not be less than $11\frac{1}{2}$ feet long.

The planking, K, shall be secured to the ribs L, L′, L″, and H, and timbers P, by at least one trenail, 12 inches long by $1\frac{1}{2}$ inch square, and one spike, 8 inches long (2 to the pound), driven through each plank into each of those ribs and timbers.

The planking, M, shall be secured by two trenails driven

through each plank into each of the ribs H, H′, and H″, and the planking N shall be spiked to M by at least two 5½-inch spikes driven through each plank, and two 9-inch spikes driven through the planks M and N, and into the rib H.

12th. Of the timbers used in the dam all the rafters, E and F, the ribs H, L, L′, L″, and the plank K and N, and the upper part of the plank M, shall be, *without exception, good heart pine.*

The residue will not be rejected if the timber be good, and of the prescribed dimensions, if it should happen to show a moderate portion of sap.

13th. There shall be a space left for a sluice in building the dam, and valves shall be fixed for the same on the upper slope. This sluice and its valves shall be made as the chief engineer shall direct; but the contractor shall be entitled to no extra allowance for the same beyond the payment at the prices stipulated in the proposals for the materials required in building the dam.

All the timber used shall be hewed or sawed square.

Abutments.—14th. The abutments, it is expected, will be of the form and dimensions exhibited in the drawing; but should there be a departure from the plan the contractor will be entitled to no allowance in consideration thereof, but shall be paid for the quantity of masonry actually contained in them at the prices stipulated in the proposal per cubic yard. A space shall be left in the northern or southern abutments as may be required by the engineer, for the purpose of permitting the passage of boats navigating the river, and for the purpose of drawing off the water from the pond. This space shall be 12 feet wide.

The whole of the abutments and wings shall be built of rubble masonry. They shall be laid partly in hydraulic and partly in common lime. Both these materials (common and hydraulic lime) shall be furnished by the Company, and used in such manner and in such proportions as the principal assistant engineer shall direct. The cement and lime shall be procured by the contractor at such places as the engineer

shall instruct him to obtain them; the Company paying for both, and the cost of their transportation; the latter (viz., the transportation) being estimated by the said principal assistant.

The masonry of the abutments and wings shall be composed of large and well shaped building stones, sufficiently dressed with the hammer to present a fair and good face. There shall be at least one header, not less than 4 feet long, running into the wall *from every face*, at every 9 feet, visible at any one time along the top of the work as it is progressing.

The arch shall be formed of well hammer-dressed stone; and all the faces of the abutments of the arch shall be well hammer-dressed, and composed exclusively of stone, well shaped, having good beds, and exceeding 2 cubic feet in size.

15th. The Company reserve the right of contracting with any other person for the building of the river lock at the passage through the abutment, and of the guard lock at the ends of the wings, and the gate at the passage through the abutment, and of requiring the contractors for the same to carry on the work during the time the dam and abutments are building.

They reserve also the right to have the embankment and puddling at the abutments done by any other contractor, or in any other way they may prefer, as the dam or walling progresses.

16th. Where the depth of the water is greater than $2\frac{1}{2}$ feet, the foundation shall be made in the manner described for the portion below the timber C, by the addition of alternate longitudinal and transverse timbers, B, B′, &c., and A, as shall be designated for each point by the engineer, it being intended that the level of the tops of all the timbers C shall remain the same.

17th. The dimensions of the dam are correctly given on the Plan, and the dimensions of the abutments and wings will be given to the contractor by the engineer on the ground, as soon as the foundations shall be made ready for building.

Note.—It is believed that advantage may be taken of the bluff of rock on the south side of the river, and that the south abutment represented in the drawing may be dispensed with.

Bill of Materials.—18th. The following bill of materials is as nearly correct as it can be made, on the supposition that the length of the dam will be 580 feet, and the depth of the water 2½ feet:

			Length in ft.		Cubic ft.
117	timbers	A,	30	12 by 12,	3510
117	ties	C,	29	12 by 12,	3393
117	rafters	E,	13¼	12 by 12,	1550
117	rafters	F,	23	12 by 12,	2691
117	braces	G,	7	12 by 12,	819
117	do.	G′,	8½	12 by 12,	994½
117	do.	G″,	5	12 by 12,	585
117	posts	D,	10	12 by 14,	1365
4	ribs	L, L′, &c.	600	10 by 10,	1667
3	do.	H′,	600	10 by 12,	1500
2	do.	H, H″,	600	12 by 12,	1200
4	stringers	B, B′, &c.	600	12 by 12,	2400
116	blocks	P,	4	9 by 12,	330
				Total square timber	22004½

Plank.

			Length in ft.	Feet B. M.
580 feet	4-inch plank	K,	14 . . .	32480
580	3 do.	M,	23 . . .	40020
580	3 do.	N,	4 . . .	6960
580	3-inch sheet piling,		4 . . .	6960
			Total plank,	86420

Iron.

351	bolts, with nuts, washers, &c., at 7 lbs. .	2457 lbs.
2400 lbs.	spikes	2400 ,,
	Total iron	4857 ,,

Trenails.

1287 trenails, 20 inches long by 2½ inches diameter.
1170 do. 12 do. 1¾ do.

Dry Wall.

1150 cubic yards vertical wall.
720 do. slope do.

Stone Filling.

2500 yards stone filling.

Mortared Masonry.

There will be from 600 to 800 cubic yards mortared masonry in the abutments, wings, &c.

SPECIFICATION OF A LOCK OF EIGHT FEET LIFT ON THE JAMES RIVER AND KANAWHA CANAL.

BENJAMIN WRIGHT, CHIEF ENGINEER.

(Plate XXXIII.)

Excavation of the Pit.—The form and dimensions of the lock pit shall be such as the engineer shall prescribe. Its slopes shall be carefully dressed, and the bottom brought to a level.

The materials excavated from the pit shall be moved to any point, not exceeding 200 feet, which shall be designated for that purpose by the engineer.

The Company reserve the right to require the whole or any part of the excavation of the pit to be done by the contractor for either of the adjoining sections.

Any material brought upon the site of the canal by the contractor for the lock shall, if required, be moved away from it before the completion of the work.

Foundation.—When a rock bottom cannot be obtained, the foundation shall be formed of hewn white oak or pine timbers, 12 inches square, laid at right angles to the axis of the lock, the middle of each timber being placed directly in the line of the centre of the lock. All these timbers shall be laid 6 inches apart, with the exception of those which are placed directly under each of the main sills, and the first four timbers next above them, which timbers (five in number

under each of the mitre sills) shall be laid side by side, and closely fitted together.

All the timbers of the foundation shall be laid horizontally, and firmly bedded either upon the bottom of the pit after it shall have been prepared for their reception, or upon gravel or such other materials as the engineer shall require to be placed there. The upper surfaces of all the timbers shall be brought to a level, and the spaces between them well filled with gravel puddling.

Over the whole area of this timber foundation shall be laid a flooring of pine plank 2½ inches thick, the part between the inner faces of the walls and covering of the bottom of the chamber being jointed and squared, and the whole flooring being secured to the timbers below by at least one trenail, 9 inches long and 1¼ inch square, driven through each plank into each of the timbers upon which it rests.

When the masonry is completed, a second course of planking, likewise squared and jointed with water-joints, shall be placed upon the first, to which and to the foundation timbers it shall be secured by two spikes in each end of each plank, and one trenail, 9 inches long, driven through each plank into each timber.

This upper course of planking shall be neatly fitted and scribed up to the inner faces of the walls, the 2 inches of the bottom of the curve of which shall be cut vertically to receive it.

The lengths and numbers of the foundation timbers shall be as follow, commencing at the head of the lock:

4	timbers	41	feet long.
2	,,	25	,,
15	,,	31	,,
51	,,	29	,,
16	,,	32	,,
7	,,	29	,,
5	,,	41	,,

Sheet Piling.—There will be four rows of sheet piling extending entirely across the foundation of the lock. It shall be composed of the best pine plank, 2½ inches thick,

and shall penetrate the earth not less than 6 feet from the top of the foundation timbers. Of the four courses there shall be one at each end of the lock, and one above each of the timbers under the main sills, and in close contact with the adjacent timbers.

The fitting and securing of this sheet piling, as well as the puddling around it, shall be done in the manner prescribed by the engineer.

Main Walls and Wings.—The main walls of the lock measure 100 feet in length between the upper sides of the two main sills, 21 feet 6 inches from the upper side of the upper main sill to the face of the upper wings, and 22 feet 6 inches from the upper side of the lower main sill to the face of the lower wings, on a level with the flooring.

The recesses will be 18 inches wide, and extend $9\frac{1}{2}$ feet above the upper sides of the main sills.

The thickness of the walls at the foundation, from a point 6 feet above the off-set forming the lower recess to a point 6 feet below the upper side of the upper main sill, will be 8 feet at the base, and 3 feet 9 inches on a level with the bottom of the coping.

This difference will be obtained in part by a batter on the face of the wall of $\frac{7}{10}$ths of a foot from the top of the coping to the surface of the water in the lower level, and partly by a curve starting tangent to this batter at the surface of the water in the lower level, and attaining the upper edge of the second course of planking in the chamber 18 inches from the vertical drawn from the origin of the curve.

The remaining difference of 2 feet and $\frac{8}{10}$ths will be distributed uniformly along the back of the wall in four equal off-sets, made at equal distances from the foundation of the wall to the bottom of the coping.

The thickness of the walls from a point 6 feet above the off-set of the lower recess to a point 6 feet below the upper side of the lower main sill, and from a point 6 feet below the upper side of the upper main sill to a point 12 feet above the same (excepting immediately at the recesses where the thick-

ness is 6 feet 6 inches), is 9 feet 6 inches. From the termination of this additional width to the commencement of the curve of the lower wing the bottom thickness is 8 feet, and opposite the breast of the lock it is 5 feet.

The upper and lower wings run out at right angles to the line of the lock, and extend at the level of the top of the coping 12 feet, and at the foundation 13 feet from the face of the main walls at the water surface in the lower level.

The upper wings are connected with the main walls by a curve described with a radius of 6 feet, and the lower wings, at the foundation, with a radius of 7 feet 6 inches.

The height of the main walls and wings, from the top of the first course of planking to the top of the coping, is 14 feet 5 inches, and the top of the first course of planking is 5 inches below the bottom of the canal.

The face of all the masonry above the upper main sill is vertical; but from the upper main sill to the extreme end of the lower wings, excepting only the lower recesses and hollow quoins, the curve from the surface of the water in the lower level to the foundation continues unbroken; and in like manner the batter of $\frac{7}{10}$ths of a foot from the top of the coping to the same surface continues from a point 5 feet below the upper side of the upper main sill to a point 5 feet above the lower recess, and from a point 5 feet below the upper side of the lower main sill to the end of the lower wings.

The chamber will be 15 feet wide at the surface of the water in the lower level, 12 feet wide at the foundation, and 16 and $\frac{4}{10}$ths feet at the top of the coping.

Over the breast wall, and for a space of 5 feet below the two main sills and 5 feet above the lower recess, the walls are vertical, and the width is 15 feet.

Face Stone.—The quarry from which the stone is obtained shall be designated or approved by the engineer; and whenever stone of suitable quality can be procured, the face, beds, and joints shall be cut.

The first or bottom course of stone shall in all cases be 12

inches in height, but the height of no succeeding course shall be less than 12 inches.

Every course shall be composed of headers and stretchers in such proportion that the space from the centre of one header to that of another shall never exceed 10 feet; and the headers shall be so distributed in the several courses that those of any one course shall be at nearly equal distances from those of the courses immediately above and below it.

The length of no stretcher shall be less than $2\frac{1}{2}$ feet, nor have less than 16 inches bed; and every face stone shall make close joints at the ends from the face back, and the full height of the course of not less than 10 inches.

The headers shall be at least 20 inches wide on the face, and shall extend into the wall with even and full beds at least 3 feet 6 inches; all that part of their beds and joints in contact with the dressed surfaces of the adjacent stretchers being well and truly cut, and both the upper and lower bed being parallel, and, when laid in the wall, horizontal. The batter in the wall above, and the curve below the surface of the water in the lower level, will be thrown into the face of the stone.

All the face stone shall be laid in full beds of good well worked mortar, extending from the face of the wall over the whole bed of the stone.

The face stones of each course shall break joints with those of the course below it at least 9 inches; and no course shall be commenced, without permission from the engineer, until the course below it shall have been laid and grouted throughout the whole length of the wall.

In the monthly estimates no account will be taken of that portion of the stretchers which may be prepared, for which there is not a due proportion of headers.

Backing.—The backing shall be composed of firm, sound, and well shaped building stone, of which not less than one-half shall exceed 2 cubic feet in bulk.

Great care shall be observed to bind the back of the masonry well with the face stone; and for this purpose there

shall be at least one header, not less than 12 inches thick, 18 inches wide, and 3 feet 6 inches long, running from the back of the wall towards the face in every 10 feet; and these headers shall be so distributed as to divide the spaces between the headers in the corresponding courses of face stone into as nearly equal parts as may be practicable.

All the stone, from the back of the lock 18 inches into the wall, and spaces 2 feet wide at every 8 feet along the wall from the back to the face, shall be well laid in full beds of mortar; and all the interstices in the wall not occupied by stone or mortar shall be completely filled with grout.

The breast wall shall be 4 feet thick at top and 6 feet at bottom, and shall be covered by a coping 4 feet wide and 1 foot thick. The height of the breast above the first course of planking is 7 feet 5 inches.

The coping and the face of the breast shall be of cut stone, similar in every respect to the coping and face stone of the main walls.

There shall be a groove or recess for stop-plank 3 inches wide and 3 inches deep in the main walls of the lock, and in a line with the centre of the breast, rising from the top of the coping of the breast to the bottom of the coping of the main walls.

The back of all the walls shall be well hammered, and the whole of the surface which shall come in contact with the puddling shall be left smooth and even.

The contractor for the lock may be required to build the dry walls at the head and foot of the lock and the paving below it; but the Company reserve the right to let either of these items to any other person, either before or after the completion of the lock.

Hollow Quoins.—There will be no hollow coin in the lower course at the upper gates, the recess for the gates being carried back their full width to the lower side of the main sill, so that the place of the hollow quoin in that course may be occupied by the timbers forming the foundation of the mitre sill. The hollow quoin in the second course shall not be less than 4 feet long, and shall form at least 10 inches of

the straight part of the recess, and extend 12 inches below the lower side of the main sill; its width shall not be less than 3 feet 6 inches in the chamber, nor less than 2 feet 6 inches in the recess, nor, when in place, less than 3 feet, measuring at right angles to the axis of the lock at any point in the curve part of its face.

The hollow quoin in the course next above shall likewise be not less than 4 feet long, and shall extend from the lower side of the main sill at least 22 inches along the straight part of the recess; its width shall not be less than 33 inches at the lower end or in the part opposite and at right angles to the chamber, nor less than 15 inches in the recess.

The remaining hollow quoins for the upper and all those for the lower gates shall be alternately of the preceding dimensions; and they shall be all well and truly cut and laid, and fill the square throughout their faces, beds, and joints.

Coping.—The face, joints, and top of the coping shall be cut full three feet back from the front of the wall, and the bottom bed as far back as it rests upon the face stone below. The bearing shall be firm and solid throughout, and the back of the coping hammered off regularly. From the recess above the upper gates to the ends of the upper wings it shall be 2 feet thick, and from the same point to the end of the berm lower wing and to the beginning of the straight part of the tow-path lower wing, it shall be 1 foot thick; but from the beginning of the straight part of the towing-path lower wing to the end of the same it shall change by a uniform descent from a thickness of 2 feet, which it shall assume at that point, to a thickness of 1 foot, which it shall acquire at the end.

The width and least admissible length of any piece of coping shall be 3 feet.

The coping around the gates, and from the upper gates to the head of the lock, shall be bound together by iron bolts and cramps.

The angle formed by the intersection of the top of the

coping and the face of the main walls and wings shall be rounded to a radius of 3 inches.

Flume.—The flume shall be formed of cast-iron pipes, of such dimensions as shall be required by the engineer.

These pipes will be furnished by the Company, and delivered by them on the basin at Richmond; but they shall be transported from the basin to the site of the lock by the contractor, the Company paying at the rate of 4 cents per ton per mile for their transportation.

The contractor for the lock will be required to leave apertures in the upper and lower berm wings for the reception of the pipes, and may be required to lay them as he carries up the puddling around the lock.

The aperture for the passage of the water through the upper wing will be 24 inches square in the face of the wing, which dimensions it shall maintain an equal distance in the wall, the upper side of this square being 12 inches below the surface of the water in the upper level, and formed by the under side of the coping; and the inner side of the square, or that nearest the face of the main wall, being 16 feet from the centre of the lock. The bottom of the square in the lower wing shall be formed by the surface of the first course of stone, and its distance from the centre of the lock shall be the same as of that in the upper wing. The four sides and back of these apertures shall be well cut.

If pipes are not provided by the time that the lock walls are sufficiently advanced to receive them, from the back of this square throughout the thickness of the wall there shall be left a horizontal cylindrical aperture 22 inches in diameter, the axis of which shall coincide with the centre of the square, so as to leave a rebate of 1 inch at the nearest points of approach of the sides of the square and the circumference of the cylinder. But if the pipes are on the ground, or ready for delivery in Richmond, when the walls are in a state to receive them, they shall be placed with their axes corresponding with the intersection of the diagonals of the square, and the masonry shall be built around them.

The joints or laps of the pipes shall be soldered with lead, as may be directed.

Cement and Sand.—The cement, put up in good barrels or casks, shall be furnished to the contractor by the Company at their depôt in the city of Richmond, or at some point on the navigable waters of the James or North River, within ten miles of their confluence. The cost of its transportation from the depôt to the site of the culvert shall be paid by the contractor, and he shall be charged at the rate of 50 cents per bushel for the amount which he receives, if obtained from the depôt at Richmond, and at the rate of 33 cents per bushel if obtained from any depôt on the James or North River; which charge of 50 or 33 cents per bushel, as the case may be, shall be deducted from his monthly and final estimates. No cement, however, shall be delivered without a written order from the principal assistant or chief engineer; and when received, even though contained in good casks, it shall be kept secure from the weather in an approved cement house until used on the work.

On presenting the written order of the engineer and receiving the cement, the contractor, or his agent or boatman, shall apply to the Company's agent, from whom he receives it, for a certificate of the quantity and quality of the cement which may be delivered to him, which certificate shall be presented to the assistant engineer on the arrival of the cement at the place where it is to be used, and it shall be the duty of said assistant to examine and compare the cement delivered there with that which the certificate calls for. And if it be found, on the completion of the lock, that the quantity of cement used in it was less than $3\frac{1}{2}$ bushels for each cubic yard of masonry, the value of the difference between the quantity used and that which ought to have been used, estimating the latter at the rate of $3\frac{1}{2}$ bushels for each cubic yard of masonry, together with the principal assistant engineer's estimate of the transportation of such difference from the depôt, whence it should have been obtained, to the site of the lock, shall be deducted from the final estimate of the work.

The cement shall be mixed with sharp and clean sand in such proportions as the engineer shall designate; and if the proportions adopted be such as to cause the quantity used to exceed the proportion of $3\frac{1}{2}$ bushels to each cubic yard, then the engineer shall estimate the value of the difference as above, which value shall be added to the final estimate of the work.

No cement shall be employed in the work which shall have been damaged on the passage from the depôt to the site of the lock, or while in the possession of the contractor, without written permission from the engineer. And in the event of the rejection of any cement so damaged, the loss of the same shall be sustained by the contractor; but if he furnish satisfactory evidence to the engineer that such cement was not damaged on the passage from the depôt to the lock, or while in his possession, and must necessarily have been injured before he received it, then the loss shall be borne by the Company, and the engineer shall estimate the cost of the transportation of such rejected cement from the depôt to the lock, the amount of which estimate shall be paid to the contractor. But if the engineer shall think proper to permit any cement which shall have been injured in the transportation, or while in the possession of the contractor, to be used in the lock, he shall estimate the value of the damage it may have sustained, which value shall be deducted from the contractor's monthly and final estimates, it being understood, however, that the estimate of such damage shall never exceed 20 cents per bushel.

The cement for all locks between Scottsville and Richmond shall be obtained from Richmond, and that which will be required for locks above Scottsville shall be procured from some point west of the Blue Ridge, and within ten miles of the head of the Blue Ridge Canal. If, however, from any cause a contractor for a lock below Scottsville shall be required to obtain his cement from a depôt west of the Blue Ridge, he shall be charged at the same rate as if he were to procure it from Richmond, but the additional cost of transportation in consequence of the change shall be estimated by the engineer, and placed to the contractor's credit.

In the same manner, any contractor for a lock above Scottsville being required to procure his cement at Richmond, shall be charged the same price for it as if he had obtained it from the western depôt, and the increase in the cost of the transportation shall be estimated by the engineer in the contractor's favour.

The sand shall be clean and sharp, and shall be passed through a screen, of which the meshes shall not exceed $\frac{1}{4}$ of an inch square. The mortar shall be worked on a plank platform in small quantities, and shall be used in the masonry before it commences setting.

Materials.—If the contractor cannot agree with the proprietor of the quarry, from whence the stone for the lock is to be obtained, for the value of the same, the President and Directors will on application cause the same to be condemned according to the charter of the Company, the contractor paying the expense of condemnation, including the damages assessed.

All the timber in the lock shall be cut at such seasons of the year as the engineer may require.

Mitre Sills.—Directly upon the first course of planking shall be laid the cross timbers forming the foundation of the upper mitre sill. These timbers, which shall be 12 inches square and 5 feet long, shall be laid parallel with the axis of the lock, and shall extend from a point 5 feet 6 inches below the front of the breast wall to the lower side of the main sill. The planking upon which these timbers rest, as well as the beds and joints of the timbers, shall be well planed; and they shall all be closely fitted together and to the walls of the recesses.

The mitre sills are placed directly upon these timbers, and are supported at each end by the projection of the curve part of the main walls, the ends of the main sills being scribed to the curves of the hollow quoins.

The mitre sills shall be of first-rate white oak, 9 inches thick; and they shall be secured to their foundation timbers,

and these to the foundation timbers of the lock, by iron bolts and trenails, as may be directed by the engineer.

The lower mitre sill shall be laid immediately upon the first course of planking over the bottom of the lock, which shall be well planed to receive it. In all other respects it will be secured and fitted to the foundations, and against the hollow quoins and lock walls, precisely as has been specified for the upper sill.

Note.—The Company reserve the right to make a separate contract with the gate-builder, or any other person, during or after the construction of the lock, to frame and lay the mitre sills; but it is understood that they shall not exercise that right without notifying the lock contractor of their intention to do so, before he shall have completed the foundation of his lock.

Any increase in the cost of the work caused by a departure from the general plan of the lock shall be estimated by the engineer, and allowed to the contractor.

No extra allowance will be made for pumping or baling water.

No spirituous liquors will be allowed to be used on the work.

SPECIFICATION FOR A LOCK OF EIGHT FEET LIFT, JAMES RIVER AND KANAWHA CANAL, VIRGINIA.

CHARLES ELLET, JUN., CHIEF ENGINEER.

(Plates XXXIV. and XXXV.)

Dimensions.—1st. The lock to be built of stone, with a facing of plank; the main walls 129½ feet long, 6 feet 9 inches thick at bottom, 5 feet 3 inches at top, and 14 feet 5 inches high.

2nd. The width in the clear at the upper mitre sill, and below the lower mitre sill, immediately above the recesses, and throughout the bottom of the lock, shall be 15 feet when the planking is on; the width between the outer faces

of the planking, at the top of the walls in the centre of the chamber, 16 feet 6 inches.

3rd. The main walls to extend 14 feet 6 inches below the centre of the curves of the lower hollow quoins, and 6 feet above the recesses for the upper gates.

4th. The breast wall to be 6 feet wide, and rise within 1 foot of the bottom of the upper level, and fill the whole space between the upper recesses and the head of the main walls of the lock.

5th. The width of the lock at the recesses to be 18 feet, and the distance from the centre of the curves of the hollow quoins to the upper ends of the recesses 9 feet.

Foundation, &c.—6th. The foundation of the lock shall consist of timbers placed at right angles to its axis, and well adjusted for the reception of the planking of the floor. To render the bearing of these timbers perfectly uniform, and secure an even surface for the bottom of the lock, there shall be a line of timbers 12 inches square, and not less than 32½ feet long, bedded firmly in the earth directly under the face of each wall.

7th. There shall be 81 timbers in the foundation of the lock. These timbers to consist of good pine or white oak, and square 12 inches. They shall be distributed as follows, beginning at the head of the lock:

4	timbers	30½	feet long—	3	spaces of	8 inches.
1	,,	34	,,	0	,,	0
4	,,	34	,,	4	,,	5
3	,,	34	,,	0	,,	0
1	,,	30½	,,	0	,,	0
51	,,	30½	,,	51	,,	9
1	,,	34	,,	0	,,	0
4	,,	34	,,	4	,,	5
3	,,	34	,,	0	,,	0
1	,,	30½	,,	0	,,	0
8	,,	30½	,,	8	,,	7½

8th. These timbers shall be laid horizontally, and firmly bedded upon the bottom of the pit, and upon the longitudinal

timbers under the faces of the walls. Their upper surfaces shall be brought as nearly as practicable to a level, and the spaces between them well filled with gravel puddling.

9th. When these foundation timbers are properly laid, they shall be alternately mortised, with two dovetail mortises. These mortises are to receive the uprights on which the planking will be nailed, and shall be so cut that when the wedges are driven the inner faces of all the posts, excepting those of the recesses, shall form two right lines on the bottom of the lock, 7 feet 9 inches from its axis. The mortises for the posts marked A in the drawing shall be in the same lines, but shall be 4 inches wide.

10th. The mortises in the timbers under the recesses shall differ from the preceding only in their position, which shall be such that when the wedges are driven the faces of the posts shall be 9 feet 3 inches from the axis of the lock.

11th. All the uprights in the chamber of the lock shall be 7 inches square, excepting those marked A, B, and C, which shall be 12 inches square. All the posts from the head of the lock down to that marked A at the upper mitre sill, and from that marked A at the lower mitre sill, up to that marked A at the upper end of the lower recess, shall be placed vertically in the lock. Those coming between these limits shall be inclined so as to form at their upper extremities a regular curve, with a versed sine of 9 inches in the middle of the chamber.

12th. The upright posts shall be mortised 8 inches into a cap-timber, 12 inches square, which shall project 3 inches beyond the inner faces of the posts.

13th. There shall be no posts, excepting that marked A, below the lower mitre sill.

14th. The portion of the bottom of the lock under the main walls shall be covered with a course of 2-inch pine planking, which shall be well jointed and secured to the timbers below by at least one trenail 9 inches long and $1\frac{1}{4}$ inch diameter, driven through each plank into each of the timbers on which it rests. When the side walls are completed, and the uprights secured in their places, this course

of planking shall be extended in the same manner over the bottom of the chamber, and closely fitted to the uprights.

Sheet Piling.—15th. There will be four rows of sheet piling extending entirely across the foundation of the lock. It shall be composed of the best pine plank, and shall penetrate the earth not less than 6 feet from the top of the foundation timbers. Of the four courses there shall be one at each end of the lock, and one above the lowest timber under each mitre sill, and in close contact with the adjacent timbers.

The fitting and securing of this sheet piling, as well as the puddling around it, shall be done in the manner prescribed by the engineer.

Main Walls.—16th. The main walls shall be built straight on the bottom, with the exception of the parts at the recesses (see Plan), but the top shall form a curve, with a versed sine of 9 inches between the upper mitre sill and the upper end of the lower recess.

17th. The walls shall consist of rubble masonry, which, with the exceptions hereafter named, shall be laid dry. This masonry shall generally be formed of large stones, with a header running at least 3 feet into the wall, both from the face and back, at least every 7 feet in each foot of the height of the wall. The stone shall be well shaped, and the bond shall be good.

18th. All that part of the side walls below the timbers B, at the lower mitre sill, shall be built vertical. It shall be laid 6 inches deep on the face, (except the part below the surface of the lower level, which shall be laid 12 inches deep,) with mortar of hydraulic cement, and be well pointed. This part of the lock will not be lined with plank. Where the wall is built round the timbers A, B, at the lower mitre sill, the face of the rebate shall be well hammered to receive those timbers.

19th. The breast wall shall be built in the same manner as the main walls, excepting that it shall be laid in cement, grouted, and coped with flags 1 foot thick, and not less than 3 feet wide and 4 feet long.

20th. There shall be a recess 12 inches square left at the junction of the upper face of the breast wall with the main walls, for the reception of the timbers A, which shall be mortised into the upper foundation timber of the lock.

21st. The face, and back, and head of the main wall, from the head of the lock down to a point 3 feet below the upper hollow quoin, shall be laid in hydraulic cement 1 foot deep, and pointed.

22nd. While building the main walls 2 anchors of 3-4 inch square iron shall be laid into them opposite each of the upright posts. These anchors shall be secured in the back of the wall by a good head bearing on a washer 3 inches square, made of 1-2 inch iron. The end projecting into the chamber shall be furnished with a well cut screw, not less than 2 inches long.

The lower of these bars shall be placed at the height of the surface of the water in the lower level, and the upper 3 feet below the top of the coping.

Timber Facing.—23rd. When the main walls are raised up to the level of the bottom of the coping, the uprights shall be placed in their mortises and secured by the keys at the bottom. They shall be placed against the side of the wall, and shall be provided with holes at the proper height to receive the screw ends of the anchors. They shall be drawn firmly up to the wall by nuts acting on these screws, and bearing on a washer of 1-4 inch iron and 2 inches square.

24th. The 12-inch square cap-timber shall be mortised 8 inches deep to receive the tenons of these uprights, and shall project over the uprights 3 inches on the face and 2 inches next the wall.

25th. The coping shall consist of flagging 12 inches thick, and shall cover the whole of the top of the wall, and be closely fitted against the cap-timbers; and the flags shall not consist of more than two pieces in the thickness of the wall.

26th. When the uprights are in place, and the first course of floor plank is laid, the sides of the chamber and recesses, and the portion of the main walls over the breast wall, shall be covered with a course of 2-inch pine plank, well jointed,

and closely fitted to the first course of floor plank, 3 inches of which shall be planed to receive it.

27th. This planking shall be secured to the upright by two 6-inch cut spikes, six to the pound, driven through each plank into each upright.

At all the corners this planking shall be fitted in the manner represented in the drawing.

28th. A second course of pine plank 1 inch thick, likewise jointed, shall be nailed to the preceding by not less than 120 tenpenny nails in each square of 100 square feet.

29th. After the posts above the upper mitre sill are set, and while the planking is being nailed on, all the spaces between the uprights, and between the planking and the wall from the posts A at the head of the lock, down to the posts B above the upper mitre sill, shall be filled with coarse grout made of hydraulic cement. This material shall be prepared and put in as the engineer may require.

Hollow Quoins.—30th. The hollow quoins shall be cut out of a 9-inch square white oak post, and curved to a radius of 6 inches. They shall be spiked to the posts A and B (to which they shall be carefully fitted) by 10 eight-inch wrought-iron spikes. The posts A and B shall each be mortised into the timbers under the foundations of the mitre sills, and anchored into the wall by 3 bolts, as specified for the uprights of the chamber.

Mitre Sills.—31st. The mitre sills, their foundations, and the gates shall be considered as excluded from this contract.

32nd. A second course of planking 2 inches thick, well planed and jointed, shall be placed on all the bottom of the lock after the sides are properly lined, excepting a space of 5 feet above and below a line drawn through the centres of the hollow quoins. This space shall be left for the reception of the mitre sills.

Wing-walls and Paving.—33rd. The bottom of the canal below the lock shall be covered with a paving extending 28

feet from the lock, and 15 feet on each side of its axis. This paving shall be formed of stone not less than 2 feet in length, and where practicable shall be set in a layer of gravel. It shall be laid with extreme care, and the spaces between the stones shall be closely filled up with spalls. The top of this paving shall be level with the flooring of the lock.

34th. The lower wings shall consist of dry masonry, and form, with the direction of the lock, an angle of 45 degrees. In the junction with the lock walls, (with which they shall not be bound in building,) the thickness of the wings at bottom shall be the same as that of the lock walls. They shall be built vertical where they start off from the end of the main walls, and have a slope of two to one where they reach the line of intersection of the surface of the water and the slope of the bank. The top and bottom of the wing-walls shall be in straight lines. The thickness next the lock shall be 4 feet at top, and at the other extremity 2 feet at top and 3 feet at bottom.

The top of these walls shall descend by a uniform slope 8 feet from the upper to the lower end. They shall be finished with a good coping, shall be founded on the paving, and shall have a column of fine spalls throughout their length, 2 feet thick, which shall be raised back of the wall from the foundation 2 feet above the surface of the water in the lower level. No extra allowance shall be made for these spalls.

35th. The length of the upper wings shall be 25 feet, and their inclination to the axis of the lock 45 degrees. They shall be founded on a course of flagging projecting 8 inches beyond the faces of the walls. This flagging shall rest on a bed of spalls, large and small, of which the upper surface shall be 9 inches below the top of the breast wall.

The part of the wing-walls next to the main walls shall be built vertical, and the part next to the extremity with a slope of two to one. A column of spalls similar to that specified for the lower wings shall be raised from the bottom to the top of these walls.

36th. All the timber and plank in this lock, excepting that in the foundation, shall consist of heart pine.

37th. The cement shall be furnished to the contractor by the Company at their depôt in the city of Richmond, or on the north branch of James River, without charge; but it shall be transported to the work by the contractor at his own expense.

Note 1. Any increase of the cost of the work, caused by a departure from the general plan of the lock, shall be estimated by the engineer, and allowed to the contractor.

2. No extra allowance will be made for pumping or baling water.

3. No contract will be made with more than one individual.

4. No spirituous liquors will be allowed to be used on the work.

SPECIFICATION FOR THE AQUEDUCT ACROSS RIVANNA RIVER, JAMES RIVER AND KANAWHA CANAL, VIRGINIA.

CHARLES ELLET, JUN., CHIEF ENGINEER.

(Plates XXXVI. and XXVII.)

With the exception of such parts as are hereafter designated, the aqueduct shall be built of the description of masonry denominated "rock work;" that is, the beds and joints shall be cut, and all the face of the stones, excepting a border of 1 inch around the edge, shall be left rough.

Arches.—There shall be three arches of 65 feet span and 15 feet rise each, of which the thickness at the crown shall be 2 feet 8 inches, and the thickness within 4 feet of the askew back 3 feet 2 inches. The segment forming the arch shall be divided into 61 equal parts, each of which shall be the width of the ring-stones and sheeting on the intrados.

The stone forming the sheeting of the arch shall be well and truly cut on every side, forming close and exact joints throughout the whole extent of the stone. No stone in the arch shall measure less than 3 feet in length, nor break joints with the stones with which it comes in contact in the adjacent courses with a lap of less than 12 inches.

The ring-stones shall consist alternately of a longer and a shorter one, of which the length of the shorter shall be not less than 2 feet, and that of the longer not less than 4 feet 6 inches. They shall be rusticated at the joints as well as on the intrados and extrados; this rustic shall be $1\frac{3}{4}$ inch, and shall project or stand in relief.

There shall be a pattern made by the engineer, and given to the contractor, for each course of the sheeting; and the whole course through and through shall be cut to that pattern, and present, when laid in the work, a perfect and uniform horizontal plane upon the intrados.

Piers and Abutments.—There shall be two piers and two abutments, and the piers shall be 7 feet thick below the torus, and shall be built with a batter of 1 inch to the foot. They shall terminate with semi-cylindrical ends, capped with a semi-conical summit, as in the Plan which has been exhibited. This semi-cone and the torus below it on each pier and abutment shall consist of the same piece of stone, and shall form the askew backs of the arches; the inclination of the upper beds of askew backs, however, having a different inclination from that of the cone.

The pilasters shall be cut and rusticated, and shall project from the face of the masonry 12 inches at top and 15 inches at bottom. To obtain this projection and form a good cone, the alternate courses of the pilasters shall extend so as to form at least 15 inches of the face of the spandrils. No stone in the pilasters shall have less than 18 inches bed.

Foundations.—The piers and abutments shall be built in coffer-dams, and, together with the wing-walls, shall be founded on the rock. The first course of stone of the piers and abutments, and of the wings, if deemed necessary by the engineer, shall be not less than 15 inches thick, and shall be formed throughout of large and well selected stone. Great care shall be taken to fit it well and evenly to the rock, so that the bearings shall be fair throughout.

This course shall be laid in a full bed of mortar with as

close joints as practicable without cutting the stone, and the whole shall be well grouted. The upper surface of the stone shall then be well dressed off, and brought to a level for the reception of the succeeding course.

Face Stones.—The coping, water table, ring-stones, pilasters, the sides of the channel or water-way, and the intrados of the arch, shall all be well cut on the faces, beds, and joints; no piece of coping shall be less than 3 feet wide, and each piece shall extend entirely across the berm or tow-path parapet, as the case may be, and project 8 inches on the outside of the wall; the coping and water table shall be cut throughout its width both on the upper and under side; the coping shall be fastened, for additional security, by iron clamps, as may be directed by the engineer.

The spandrils, wings, piers, and abutments shall consist of "rock work," of which the beds and joints shall be cut and laid in courses; no course of stone shall be less than 12 inches in height, and the height of no succeeding course shall exceed that of any course below it; every course shall be composed of headers and stretchers in such proportion that the space from the centre of one header to that of another shall never exceed 10 feet; and the headers shall be so distributed in the several courses, that those of any one course shall be at nearly equal distances from those of the courses immediately above and below it.

The length of no stretcher shall be less than $2\frac{1}{2}$ feet, nor have less than 16 inches bed, and every face stone shall make close joints at the beds from the face back, and the full height of the course of not less than 10 inches.

The headers shall be at least 20 inches wide on the face, and shall extend into the wall with even and full beds, at least 3 feet 6 inches; and that part of their beds and joints in contact with the dressed surfaces of the adjacent stretchers being well and truly cut, and both the upper and lower bed being parallel, and when laid in the wall horizontal. The batter in the sides of the water-way shall be thrown into the face of the stones.

The face stones of each course shall break joints with those of the course below it at least 9 inches, and no course shall be commenced without permission from the engineer, until the course below it shall have been laid and grouted throughout the whole length of the wall. All the face stone shall be laid in full beds of good well worked mortar, and the backing dead work shall be laid in full beds of mortar, or grouted, at the option of the engineer.

In the monthly estimates no account will be taken of that portion of the stretchers which may be prepared, for which there is not a due proportion of headers.

The backing of the spandrils and wings shall be composed of large, sound, and well shaped building stones.

In the piers and abutments the headers on the one side shall be so distributed as to divide the spaces between the headers on the other, and the backing shall be selected and laid with extreme care.

The back of all the masonry which will come in contact with the puddling shall be well hammered off and properly pointed.

The bottom of the water-way shall either be formed of flagging, cut at the joints, with parallel beds, and laid in a full bed of mortar, or of broken stone laid in grout, at the option of the engineer.

[The clauses relating to the cement, &c. are similar to those inserted in pages 143 to 145.]

Proposals—Masonry.

For the masonry of the arches, per cubic yard .	$19 75
For all other masonry in the aqueduct, per cubic yard	8 50

Foundations.

For all rock excavation in the foundations, per cubic yard	$1 50
For excavation of all other materials, per cubic yard	0 25

SPECIFICATION FOR THE SUPERSTRUCTURE OF THE FARM BRIDGES ON THE JAMES RIVER AND KANAWHA CANAL.

CHARLES ELLET, JUN., CHIEF ENGINEER.

(Plate XXXVIII.)

The span or clear opening of the Farm Bridge shall be 49 feet, the width of the tow-path 6 feet, and that of the waterway directly under the bridge 40 feet.

The under sides of the principal strings or beams shall be at least 10½ feet above the surface of the water. The width of the bridge in the clear shall be 10 feet 4 inches, and from outside to outside 12 feet.

Superstructure.—The superstructure of the bridge shall be formed of two trusses framed as in the Plan which has been exhibited. The timbers in the trusses shall consist of first-rate heart yellow pine, put together with care and accuracy, the braces and all sustaining parts being drawn home by the bolts represented in the drawing. These bolts shall consist of 1-inch iron, and shall be secured by suitable burrs, bearing upon an iron plate or washer. The four principal bolts shall pass through the centre of the queen posts, and suspend the cross beams on the under side of the principal strings.

In raising the bridge, there shall be a coat of coal tar put between the surfaces of the timbers which are in contact, in all the mortises, and in all the holes occupied by bolts.

On the completion of the bridge, the whole of its surface which is exposed to the weather shall be well whitewashed.

The superstructure of the bridge shall be formed from the following bill of timber:

No. of Pieces.	Length. Feet.	Dimensions. In. In.	Quantity. B. M.	
2	54	12 × 12	1296	Main beams.
2	17½	10 × 8	233	Collar beams.
4	17½	10 × 8	467	Truss beams.
4	5½	11 × 8	161	Queen posts.

No. of Pieces.	Length. Feet.	Dimensions. In. In.	Quantity. B. M.	
2	14	11 × 9	231	Transverse beams.
4	6	11 × 12	264	Bolsters.
4	18½	9 × 6	333	Floor beams.
6	20	9 × 6	540	Floor beams.
2	18	9 × 6	162	Floor beams.
4	12	8 × 3	96	Wall plates.
4	18	4 × 8	192	Rails.
4	2½	4 × 8	27	Posts.
	54 × 10		1350	2½-inch floor plank.

SPECIFICATION FOR THE ABUTMENTS, WALLING, &c. OF THE FARM BRIDGES ON THE JAMES RIVER AND KANAWHA CANAL.

(See also Plate XXXVIII.)

The span or clear opening of the Farm Bridge shall be 49 feet, the width of the tow-path 6 feet, and that of the water-way directly under the bridge 40 feet.

The under sides of the principal strings or beams shall be at least 9½ feet above the surface of the water. The width of the bridge in the clear shall be 10 feet 4 inches, and from outside to outside 12 feet.

The reduction in the width of the water-way shall be made on the berm side of the canal, and shall continue in the direction of the canal no further than the length of the face of the abutments and wings.

The banks of the canal under the bridge on the tow-path side, and if required, adjacent to the wings on the berm side, shall be protected by a slope wall 2 feet thick at bottom, and 18 inches thick at top; the first having a slope of one and a half horizontal, to one in the rise; and the second, the direction that may be required by the engineer. The foundations of these walls shall not be less than 6 inches below the bottom of the canal, and the walls shall rise to the level of

the towing-path, where they shall be finished by a substantial coping.

The space between the first of these walls and the abutment shall be covered with a layer, 6 inches thick, of good clean gravel or finely broken stone.

Abutments and Wings.—The inner face of the abutment, on the towing-path side, shall be placed 34 feet, and that on the berm side 15 feet, from the centre line of the canal. Where deemed necessary by the engineer, the abutments and wings on both sides shall be built on timber foundations, which shall be formed of timbers 12 inches square, and laid 2 feet apart from centre to centre, and parallel with the axis of the bridge. The spaces between the timbers shall be filled up with gravel or broken stone well rammed, and the whole covered by a course of planking 2 inches thick, secured to the timbers by trenails as may be directed.

The abutments and wings shall consist of dry well hammer-dressed rubble masonry. The top of the abutments shall be at least 10½ feet above the surface of the water in the canal, and 3½ feet thick. The thickness of the wings below the coping shall be 2 feet 6 inches at the lower end, and 3 feet at the shoulder, measured at right angles to the face of the walls.

The exposed faces of the walls shall be vertical, and the back shall have a batter of 1½ inch for each foot of height, and 2 inches for each foot at the ends of the wings.

Six inches on the exterior faces of the abutments and wings shall be laid in cement and be well pointed. The cement for this purpose shall be furnished by the Company at their depôt at Westham, (or at Richmond, after the navigation between that place and Westham shall be re-opened,) or on the Blue Ridge Canal, as shall be directed by the assistant engineer, and shall be transported thence to the work by the contractor at his own cost.

The wings shall be covered by a hammer-dressed coping from 9 to 12 inches thick.

No contract will be made with more than one individual.

SPECIFICATION FOR THE AQUEDUCT ACROSS BYRD CREEK, JAMES RIVER AND KANAWHA CANAL.

CHARLES ELLET, JUN., CHIEF ENGINEER, AND BENJAMIN WRIGHT, CONSULTING ENGINEER.

(Plates XXXIX. and XL.)

With the exception of such parts as shall be specified hereafter, the aqueduct shall be built of the description of masonry denominated "rock work;" that is to say, the beds and joints and a border of one inch around the edge shall be cut, the rest of the stone being left rough.

Arch.—There shall be one arch of 50 feet span and 7 feet rise, of which the thickness at the crown shall be 2 feet and 8 inches; and the thickness at the askew back not less than 3 feet and 2 inches. The form of the arch shall be a segment of a circle, which shall be divided into forty-three equal spaces, each of which shall be the width of the ring-stone and the sheeting, on the intrados. The stone forming the sheeting or voussoirs of the arch shall be well and truly cut on every side, and form close and exact beds and joints throughout the whole extent of the stone. No stone in the arch shall measure less than 3 feet in length, nor break joints with the stones which it is in contact with in the adjacent courses, with a lap of less than 12 inches. The ring-stones shall consist alternately of a longer and shorter one, of which the length of the shorter shall not be less than 3 feet, nor that of the longer less than 4 feet and 6 inches. They shall be rusticated at the joints with a rustic of 1½ inch. The rustic shall project or stand in relief. There shall be a pattern made by the engineer and given to the contractor for each course of the sheeting, and the whole course through and through shall be cut to that pattern, and present, when laid in the course, a perfect and uniform horizontal plane upon the extrados.

Abutments and Wings.—The face of the abutments under

the arch shall project 4 feet beyond the plane of the face of the wing-walls, which projection shall terminate at the ends by a quarter cylinder, crowned with a quarter cone, as represented in the drawing. This quarter cone, and if required by the engineer, the torus below it, on each abutment shall consist of the same piece of stone, and shall form the first of the askew backs of the arch, the inclination of the upper bed of the askew back, however, being different from the inclination of the cone.

The face of the masonry of the abutments and wing-walls shall be vertical.

The square corners and the ends of the wings shall be finished by pilasters, of which the projection from the face of the wall shall be 12 inches. To obtain this projection and make a good bond, the alternate courses of the pilasters shall extend so as to form at least 15 inches of the face of the wings.

The pilasters and the cylindrical ends of the abutments shall be cut and rusticated with a square rustic, and no stone shall be admitted into either of the pilasters or into any part of the face of the abutment having less than 18 inches bed.

Parapet Walls.—The width of the aqueduct from outside to outside of the parapets at the level of the bottom of the canal shall be 33 feet, of which space 20 feet shall be appropriated to the water-way, 8 feet to the tow-path, and 5 feet to the berm parapet. The top of the water table shall be level with the bottom of the canal, and the height from the top of the water table to the top of the coping of the parapets shall be 6 feet 6 inches. The sides of the water-way shall be smoothly cut, and the backing of the parapets, as well as of every other part of the masonry, shall be substantially laid, and rendered as near perfectly water-tight as the nature of the work will admit.

Foundations.—The wings and abutments shall be built in coffer-dam, and founded on the rock. The first course of masonry shall be not less than 16 inches high, projecting

9 inches beyond the face of the walls, and formed throughout of large and well selected stones, placed alternately in the form of header and stretcher. This course shall be laid in a full bed of mortar with as close joints as may be practicable to make without cutting the stone. It shall be well grouted, and great care shall be taken to fit it well and evenly to the rock, so that the bearing shall be fair throughout.

Face Stone.—The coping, water table, ring-stones, pilasters, the cylindrical ends of the projecting part of the abutments, the sides of the channel or water-way, and the intrados of the arch, shall be all well cut on the faces, beds, and joints. No piece of coping shall be less than 3 feet wide, and each piece shall extend entirely across the berm or tow-path parapet, as the case may be, and project 8 inches on the outside of the wall. The coping and water table shall be cut throughout its width both on its upper and under side; the coping shall be fastened for additional security by iron clamps, as may be directed by the engineer. The spandrils, wing, and abutments shall consist of rock work, of which the beds and joints shall be cut and laid in courses. No course of stone shall be less than 12 inches in height, and the height of no successive course shall exceed that of any course below it. Every course shall be composed of headers and stretchers in such proportion that the space from the centre of one header to that of another shall never exceed 10 feet, and the headers shall be so distributed in the several courses that those of any one course shall be at nearly equal distances from those of the courses immediately above it and below it.

The length of the stretchers shall not be less than $2\frac{1}{2}$ feet, nor have less than 16 inches bed, and every face stone shall make close joints at the beds, from the face back, and the full height of the course of not less than 10 inches. The headers shall be at least 20 inches wide on the face, and shall extend into the wall with even and full beds at least 3 feet 6 inches, and that part of the beds and joints in contact with the dressed surface of the adjacent stone being well and truly cut, the upper and lower bed being parallel,

and, when laid on the wall, horizontal. The batter on the sides of the water-way shall be thrown into the face of the stone. The face stone of each course shall break joints with those of the course below it, at least 9 inches, and no course shall be commenced without permission from the engineer, until the course below it shall have been laid and grouted throughout the whole length of the wall. All the face stone shall be laid in good well worked mortar, and the backing dead work shall be laid in full beds of mortar, or grouted, at the option of the engineer. In the monthly estimates no account will be taken of that portion of stretchers which may be prepared, for which there is not a due proportion of headers. The backing of the spandrils and wings shall be composed of large, sound, and well shaped building stones. The backing of all the masonry which will come in contact with the puddling shall be well hammered off and properly pointed. The bottom of the water-way shall be either formed of flagging cut at the joints, with parallel beds, and laid in full beds of mortar, or of broken stone laid in grout, at the option of the engineer.

[The clauses of the Specification which refer to the cement and sand to be used, the quality of the stone, and the making out of the monthly estimates of work done, are similar to those given in pages 143 to 145.]

Final Estimate on the Byrd Creek Aqueduct, Jan. 1st, 1839.

259½	cubic yards of masonry of the arch	@ $20 00	5,190	00
590	,, rubble masonry .	8 00	4,720	00
2118½	,, all other masonry .	9 50	20,125	75
280	,, excavation of rock .	1 50	420	00
4300	,, all other materials .	0 35	1,505	00
152	,, dry walling . .	2 50	380	00
5000	,, puddling . .	0 30	1,500	00
18	,, masonry removed .	2 25	40	50
1070	feet (board measure) 2-inch plank	0 25	26	75
	Extra work behind the askew backs	@ E. E.	565	00
			$34,473	00

SPECIFICATION FOR THE LOCK GATES, MITRE SILLS, AND FOUNDATION FOR THE UPPER MITRE SILLS OF THE LOCKS OF THE JAMES RIVER AND KANAWHA CANAL.

Lift 8 *feet.—Lower Gates.*—1st. All the materials in the frame of the gates, including the planks, shall be of heart pine timber; and the whole shall be well planed.

2nd. The form and manner of framing the gates shall be exhibited in the working drawing, which shall be furnished to the contractor.

3rd. The height of the lower gate, from the top of the upper arm to the bottom of the lower one, shall be 12 feet 11 inches, and that of the upper gate 11 feet 11 inches, and shall be distributed among the seven arms and six inter-spaces, as shown in the drawing.

4th. The spaces between the inner faces of the head and heel posts shall be 7 feet and ½ an inch; and the former shall be cut out of a piece 10 inches square, and the latter out of a piece 12 by 14 inches.

5th. The balance beam shall be 23 feet long and 15 inches square at the larger end, and 11 inches by 10 inches at the point where it unites with the head post. In framing the gate the space between the upper side of the upper arm and the under side of the balance beam, at the joints of their contact with the inner face of the head post, shall be 7 inches; and the space between the same pieces at a point directly over the line of contact of the upper surface of the upper arm and the inner face of the heel post shall be 15 inches. The balance beam shall diminish or taper off uniformly from the larger to the smaller end.

6th. The head post shall rise 4 inches above the balance beam, and descend 2 inches below the lower arm; and the part projecting above the balance beam shall be bound by a ring 3 inches wide by ½ an inch thick; and the part below the lower arm shall be bound by a ring 2 inches wide by ½ an inch thick.

7th. The heel post shall descend 2 inches below the lower

arm, and shall be bound by a ring 2 inches wide and ½ an inch thick. The rings on the head post shall be 9 inches diameter in the clear, and that on the heel post 11 inches diameter in the clear.

8th. The thickness of the gate shall be 12 inches at the centre of the heel post, and 10 inches at the inner face of the head post.

9th. The planking of the gate shall be 2 inches thick, and shall be placed vertically, and shall be so secured that the upper surface shall be in the same plane with the upper sides of the heel and head posts; and for this purpose there shall be a rebate 2 inches wide and 2 inches deep cut in the upper arm, and the one next to the bottom to receive the ends of the plank, and the four intermediate bars shall recede on the upper side 2 inches from the plane of the upper faces of the heel and head posts. The plank shall be fitted with water joints, and shall be secured with not less than one hundred 5-inch wrought-iron spikes in each gate.

10th. All the tenons shall be 3 inches thick at the head, and 4 inches at the heel posts, and shall extend 7 inches into the heel and 5 inches into the head posts.

11th. The tenon upon the balance beam shall be but 7 inches in height, so as to leave 8 inches of stuff between the upper side of the mortise and the top of the head post; and there shall be a bolt of 1¼-inch square iron passed vertically through the centre of the balance beam and the centre of the upper arm, and at a point 6 inches from the inner face of the head post. The head of this bolt shall bear on a washer on the upper side of the balance beam, and shall be drawn home by a nut, bearing likewise on a washer on the under side of the upper arm.

12th. There shall be a set of T and L plates made of iron 2½ inches wide by ⅝ thick, passing round both ends of the two lower bars, at the connexion of the upper bar with the heel post, and at the connexion of the balance beam and upper arm with the head post. The form and position of these plates are designated in the drawing. There shall be a set on each side of the gates, in the making of which the

holes shall be drilled through each set at the same time while the iron is cold. The bolts shall be formed of $\frac{3}{4}$-inch iron, with square heads, and shall be drawn home by sufficient nuts.

13th. There shall be a coat of coal tar placed in all the mortises, under all the irons, and in all the holes occupied by bolts.

Specifications for Mitre Sills. — Foundation. — 14th. The foundation of the upper mitre sill shall be formed as described in the printed specifications for the locks, of heart pine timber, 12 inches square and 5 feet long, laid parallel with the axis of the locks from a line drawn transversely across the lock 5 feet 6 inches below the front of the breast wall. These timbers shall be laid directly on the first course of planking, which shall be smoothly planed to receive them. They shall be accurately fitted together and bolted down to the foundation, by at least two bolts 2 feet long, and formed of 1-inch square iron, driven through the timbers and the flooring, and 10 inches into the foundation timbers of the lock. The upper surface of these timbers shall be smoothly planed for the reception of the mitre sill.

15th. The upper mitre sill shall be 12 inches wide by 9 inches thick, and when laid shall be 16 inches above the bottom of the canal. The inclination of the lower side of the leaves of the gate, or the upper side of the sills, to the line joining their extremities, will be that of an angle of which the tangent will be three-eighths of the radius. The position of the sill will be obtained by describing a circle with a radius of 6 inches, and having its centre to coincide with the centre of the curve of the hollow quoin; and drawing a line tangent to this circle, and perpendicular to that radius, which makes the same angle with the lock (viz. tang. $= \frac{3}{8}$) which the inclination of the mitre sill must make with the perpendicular to the axis. This is shown more clearly in the drawing.

16th. From the lower end of the two middle timbers of the foundation to the point of the salient angle of the sill,

there shall be placed a timber 12 inches wide and 9 inches thick for the purpose of a brace. The mode in which the angle of the sill is notched to this tongue or brace, as well as the number and position of the bolts by which both it and the sill are secured to the foundation, is represented in the drawing. These bolts shall be 30 inches long, and formed of 1-inch square iron.

17th. The form and dimensions of the lower mitre sill differ in no respect from those of the upper one. It shall be laid, however, upon the first course of planking, which shall be well planed to receive it.

18th. The contractor for the gates shall finish that part of the upper course of the flooring of the lock next to the lower mitre sill, which may be left unclosed by the contractor for the lock; and if he be required to furnish the timber (which shall be heart pine), he shall be paid for the materials and workmanship at the rate of per thousand feet board measure for the workmanship and materials which shall be required; but if the Company furnish the materials, he shall be paid at the rate of per thousand feet for the workmanship. All the bolts used in securing the mitre sills, and the foundation for the upper sill, shall be feathered.

Bill of Timber and Iron.

2 upper mitre sills 9 feet long, 12 × 9 .	162 *f. b. m.*
1 brace do. 4 do. 12 × 9 .	36 *f. b. m.*
12 iron bolts 30 inches long, 1 inch square	114 *lbs.*
2 lower mitre sills	198 *f. b. m.*
12 iron bolts 24 inches long, 1 inch square	85 *lbs.*
18 foundation timbers for upper mitre sills, 5 feet long, 12 × 12	1080 *f. b. m.*
24 iron bolts 24 inches long, 1 inch square	180 *lbs.*

19th. The proposal of the contractor is made on the supposition that the following will be the bill of timbers and iron for the gates, and the above bill (18), that for the mitre sills, and foundation of the upper mitre sill, for a lock of 8 feet lift.

Bill of Timber for a Lock Gate for a Lock of 8 feet lift.

No. of pieces.	Length. ft.	in.	Dimension.	Ft. b. m.	Description.
1	13	6	14 × 12	217	Heel post.
1	15	6	10 × 10	129	Head post.
1	8	3	7 × 10 7 × 12	54	7th or upper arm.
1	8	3	5 × 10 5 × 8	31	6th arm.
1	8	3	5 × 10 5 × 8	31	5th arm.
1	8	3	6 × 10 6 × 8	34	4th arm.
1	8	3	6½ × 10 6½ × 8	40	3rd arm.
1	8	3	8 × 10 8 × 8	60	2nd arm.
1	8	3	8 × 10 8 × 8	60	1st or lower arm.
1	23	0	15 × 15 10 × 10	300	Balance beam.
			10½ × 7	147	Two-inch plank.
				1103	

Iron Work.

No of pieces.	ft.	in.	in.	lbs.	Description.
1	3¼	3 ×	½	17	Hoop on heel post.
2	2¾	3 ×	½	28	Hoop on head post.
4	5	2½ ×	⅝	105	L plates on lower bar.
2		2½ ×	⅝	52	L plates on upper bar and balance beam.
2	3	2½ ×	⅝	31	T plates.
	inches.				
16	11	¾	diameter	70	Round bolts for head plates.
12	13	¾			Do. do. do. and heel.
2	26	1		13	Do. do. do. balance beam.
				316	

Collars and anchors assumed at 60 lbs. for each gate, and to be of iron 2½ by ⅝, and of the length given on the Plan. Castings for step and socket 80 lbs. for each gate, and of the form shown in the Plan.

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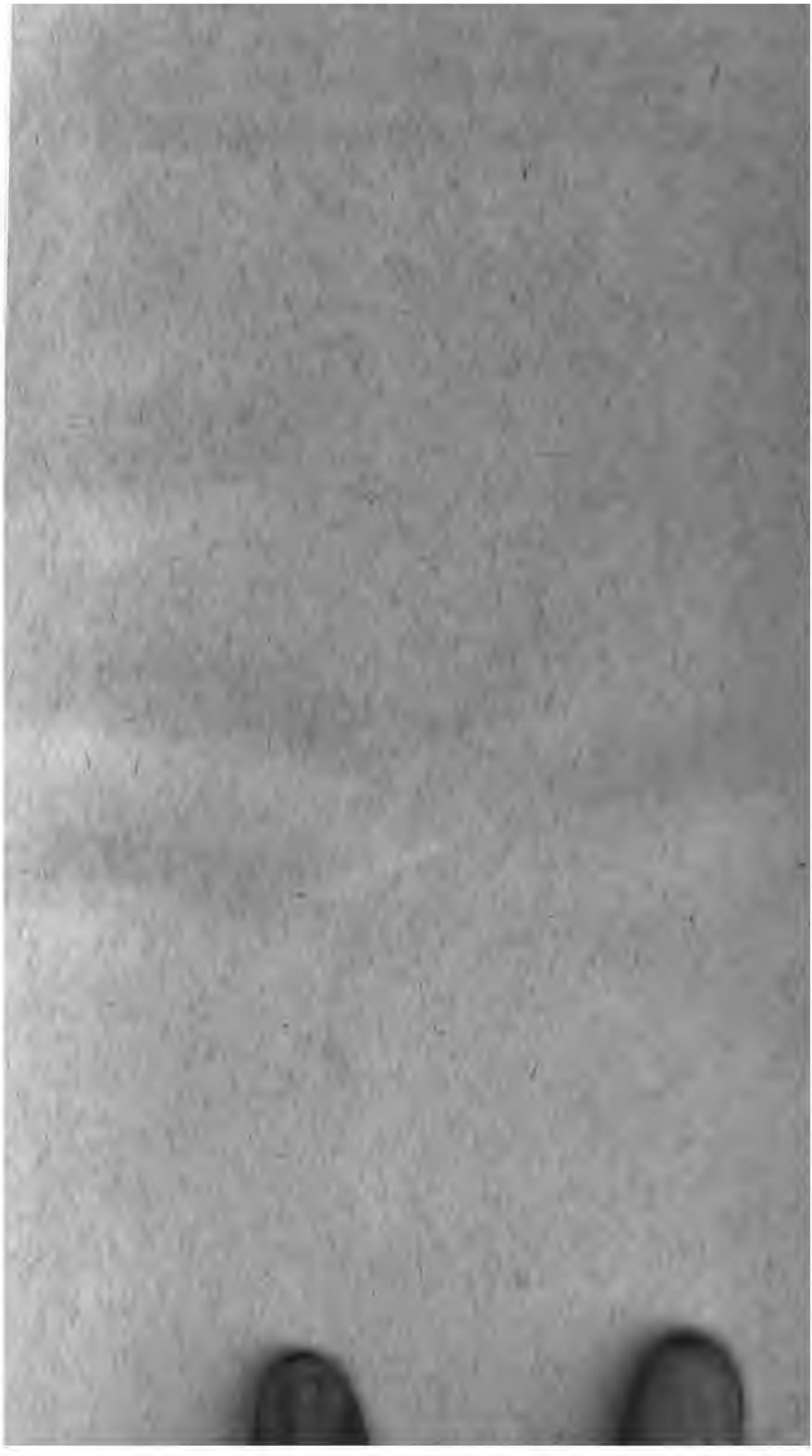

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